Kaizen Productive Strategy in Different Scenarios - Gearbox and Hydraulic Components Manufacturing and Furniture Supply Chains

Francisco Gonçalves Montenegro Chaves

Dissertation Project / Final Thesis

Supervisor at FEUP: Prof. João Manuel R.S. Tavares

Supervisor at *Kaizen* Institute: Eng. Bruno Fabiano

U. PORTO

FEUP FACULDADE DE ENGENHARIA UNIVERSIDADE DO PORTO

Master in Mechanical Engineering

February 2017

Aos meus Pais e à minha irmã Joana.
Devo-lhes tudo.

"In God we trust. All others bring data."
E. Deming

Abstract

The present Dissertation Project aims to report the implementation of *Kaizen* Productive Strategies and *Lean* Tools in three different companies located in Italy in the period of aproximately six months.

Each company dealt with different demands, difficulties and challenges, and each had its own type of products and specificities of market.

This thesis contains a detailed description of the implementation of Total Productive Maintenance (Scenario A and B), in a gearbox supply chain and in a hydraulic component production group, and Stock Reduction in a furniture company (Scenario C).

Comparison between implementation difficulties and change management effectiveness are also established, with attention to cultural diferences, specificity of product, political impediments and geographical location.

The main tools used and detailed include, SMED, 5s, Total Productive Maintenance, Kanban Systems and Kraljic's Matrix.

In the implementation of the referred solutions, layout redesign, tool change reduction, improvement of workplace house-keeping, data collection systems, maintenance standards, workshops and risk analysis were carried out and implemented, constituting improvements for the companies represented.

The work described was carried out in the position of an external consultant, from a *Lean* consulting group.

Some of the results achieved were:

- Scenario A: Reduction of 48,1% in setup time, representing an annual saving of 25 389 €;
- Scenario B: Reduction of 86,2% in setup time and zero breakdowns or malfunctions in the machines since TPM intervention, representing an annual saving of 22 464 €;
- Scenario C: Reduction of 10,3% of the global value of warehouse stock, constituting 41,5% of the proposed goal, after study of only two suppliers of, approximately, 100 suppliers, representing an immediate saving of 83 000 € of merchandise in warehouse.

Resumo

O presente Projeto de Dissertação tem como objetivo relatar a implementação de Estratégias Produtivas *Kaizen* e ferramentas *Lean*, em três empresas italianas, num período de aproximadamente seis meses.

Cada empresa lida com diferentes procuras, dificuldades e desafios, tendo cada uma uma tipologia de produtos diferente e especificidades próprias de cada mercado.

Nesta dissertação estão presentes as descrições da implementação de "*Total Productive Maintenance"* (Caso A e B), numa cadeia de abastecimento de moto-redutores e num grupo de componentes hidráulicos, e da redução de stock numa empresa produtora de móveis (Caso C).

É feita uma comparação entre as dificuldades de implementação e eficiência da gestão da mudança entre os três casos, prestando atenção às diferenças culturais, especificidade de produto, impedimentos políticos e localização geográfica.

As principais ferramentas utlizadas incluem SMED, 5s, *Total Productive Maintenance*, sistemas Kanban e matriz de Kraljic.

Durante a implementação das soluções referidas, foram realizadas redefinições de layout, redução dos tempos de Setup, melhorias nos espaços de trabalho, criação de standards de manutenção, sistemas de recolha de dados e tratamento, workshops e métodos de análise de risco, constituindo melhorias para as empresas retratadas.

O trabalho descrito foi realizado na posição de consultor externo, na representação de uma consultora especializada na implementação de *Lean*.

Alguns dos resultados atingidos foram:

- Caso A: redução dos tempos de Setup em 48,1%, representando 25 389 € de poupança anual;
- Caso B: redução dos tempos de Setup em 86,2% e nenhuma avaria nas máquinas-ferramenta desde a intervenção TPM, representando 22 464 € de poupança anual;
- Caso C: redução de 10,3% do valor global em armazém, representando 41,5% do objetivo proposto pela empresa, após análise de apenas dois fornecedores, de um total de aproximadamente 100 fornecedores, representando 83 000 € de poupança imediata em armazém.

Abstract

La presente Tesi ha come obiettivo di presentare l'implementazione della strategia *Kaizen* e degli strumenti *Lean* in tre differenti realtà industriali presenti sul territorio italiano in un periodo di circa 6 mesi.

Ognuna di queste tre società affronta sfide, difficoltà e richieste cliente diverse tipiche del mercato di riferimento.

Questa tesi contiene una descrizione dettagliata dell'implementazione del TPM (Total Productive Maintenance) - caso A e B – nella *supply chain* dei riduttori e nella produzione di componentistica oleodinamica, e riduzione stock in un'azienda di arredamenti di interni – caso C.

Viene riportato anche il confronto tra la difficoltà di implementazione delle soluzioni tecniche e l'efficacia della gestione del cambiamento, con particolare attenzione alle differenze culturali dei dipendenti dell'azienda, alle specificità del prodotto, alle problematiche sindacali e alla posizione geografica dei siti produttivi.

I principali strumenti utilizzati sono lo SMED, le 5S, il Total Productive Maintenance, il sistema Kanban e la Matrice di Kraljic.

L'implementazione delle soluzioni, di relayout, di riduzione del cambio utensile, di miglioramento della postazione di lavoro, del sistema di raccolta dati, dello standard di manutenzione, hanno portato a miglioramenti di performance per le aziende rappresentate.

Il lavoro descritto è stato seguito da un consulente esterno appartenente ad una società di consulenza di *Lean* Management.

Di seguito sono riportati alcuni risultati raggiunti:

- Caso A: riduzione del 48,1% del tempo di setup, rappresentando 25 389 € di risparmio annuale;
- Caso B: riduzione del 86,2% del tempo di setup e zero guasti o malfunzionamenti sulle macchine da quando è stato fatto l'intervento TPM, rappresentando 22 464 € di risparmio annuale;
- Caso C: riduzione del 10,3% del valore dello stock presente in magazzino. Tale riduzione risulta essere il 41,5% dell'obiettivo prefissato solamente intervenendo su due fornitori, di un totale di aprossimatamente 100 fornitori, rappresentando un risparmio di 83 000 € in magazzino.

Acknowledgments

I would like to thank the teams of Rossi, Brevini Fluid Power and Alf, for all their cooperation and their willingness to change and grow.

I would also like to leave a very special note to everyone at the Kaizen Institute Italy, for their faith in me, their vast knowledge and for all the friendship they gave me - To those with whom I worked the most, a special highlight to Eng. Bruno Fabiano, Eng. Giancarlo Gavioli, Eng. Alessio Vignato and Eng. Emanuele Govetto, who taught me so much and shared so many insights.

I cannot go on without referring Prof. João Tavares for his endless support and knowledge, which definitely were essential for my learning process and for my evolution as a starting professional.

I'd also like to leave my gratitude with the Erasmus+: Internship program that has been knocking down international borders and barriers, working for an idyllic Europe, without impediments for one's learning and growth.

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Glossary

Bullwhip effect – Increased fluctuation in quantity orders from customer to supplier inside a supply chain, creating larger variance than the sales to the end costumer.

Cycle Time – Time consumed to produce one unit of product.

Gemba - Japanese word for "Where the action happens". Gemba is used to describe the place where value-added operations occur.

Heijunka – Japanese for production leveling. The term was coined at Toyota Motor Corporation.

Jidoka – Japanese for autonomation. Means automation with intelligence, stops when errors are detected, automatically.

Junjo – Ordered supply of components.

Just-In-Time – production management system, where exact quantities must be supplied at an exact moment, at an exact place.

KPI – Key Performance Indicator

Lead Time – Time from the beginning of production until completion.

Muda – Japanese for waste, or inefficiency.

Kaizen – Japanese for "change for the better". Also referred to as continuous improvement.

Kanban – Material replenishment system used for material flow control.

SKU – Initials of "Stock Keeping Unit". Designates different stock items.

SMED – Initials of "Single Minute Exchange of Dies". Method for severe tool-change reduction.

Takt Time – Time the market consumes/demands one unit of product, market's demand pace. German for pulse.

TFM – Total Flow Management

TPM – Total Productive Maintenance

VSD – Value Stream Design

VSM – Value Stream Mapping

WIP – Work In Progress. Uncompleted units or batches of product.

5s – Japanese method for workplace organization. Acronym composed by five words: Sort, Straighten, Shine, Standardize, Sustain.

List of Figures

Chapter 1: Introduction

The present thesis, was developed under the scope of the Master in Mechanical Engineering, from the Faculty of Engineering of the University of Porto.

The projects described were developed while performing an internship at the *Kaizen* Institute, in Italy, within a period of aproximately six months.

During this internship, three projects were assined, alongside the main topics to implement, thouroughly described in this chapter.

In this chapter, the *Kaizen* Institute is presented, alongside with its clients, who hired *Kaizen* to intervene and implement *Kaizen* and *Lean* tools. Each client is presented, following the objectives of each Scenario and a brief indication of the methodologies to be used.

The three companies are: Rossi SPA (producer of gearboxes), Brevini Fluid Power (producer of hydraulic components) and Alf (producer of furniture).

1.1 *Kaizen* Institute **Consulting Group**

The *Kaizen* Institute was founded by Masaaki Imai in 1985, and holds its mission to spread and implement *Kaizen* all over the world. The group's logo is visible in Figure 1.

Figure 1: *Kaizen* Institute's logo (Institute, 2016).

Kaizen Institute is present in more than 40 countries, and has been leading growth in innumerous sectors of activity and industries, having offices in over 30 countries. (Institute, 2016)

The *Kaizen* Institute differs from common consulting groups, being characterized by the utilization of *Lean* and Industrial tools, as part of their Business Technology, allied to a very well defined set of Change Management Tools, summarized in Figure 2.

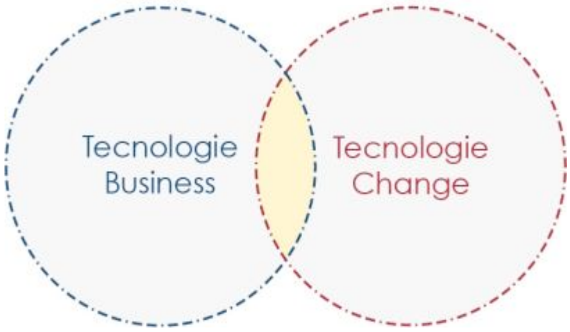


Figure 2: Venn diagram of Kaizen Institute's methodology (Business Technology and Change Technology) (Institute, K., 2016).

The combination of these two strategies allow the *Kaizen* Institute to implement efficient management systems, tailored to their client's needs, involving employees from different levels and degrees of intervention, enabling change, acceptance and growth, with low levels of resistance to change.

One of the ways Kaizen Institute approaches change, is through the "*Kaizen* Process", which can be viewed on figure 3. This process describes the steps of a normal workshop. The "heart", illustrates motivation. The problem to be solved. The "Eye", observation. Data collection and grasping the problem, whereas "Try Storm" represents experimentation, and "Implement" the act of choosing one of the previous findings, implementing it and testing it. Then, standardization of the new found solution.

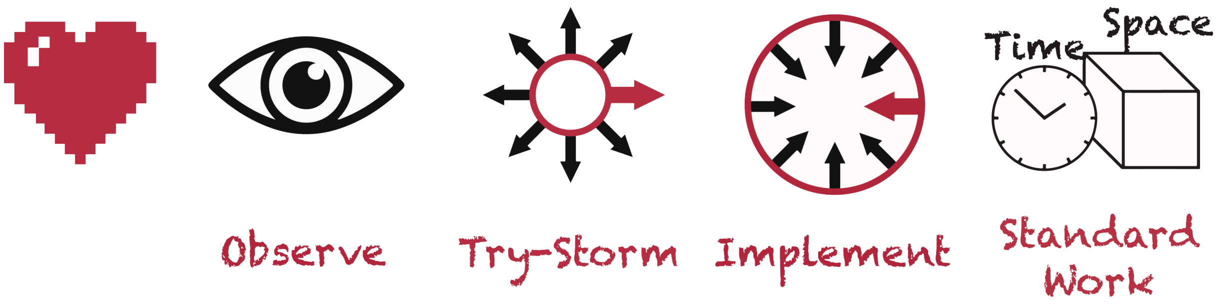


Figure 3: The "*Kaizen* Process" for workshops (Institute, 2016).

1.2 Scenario A - Rossi SPA

Presentation of the company

Rossi Motoriduttori has been producing gear reducers, gear motors and electric motors since 1953, being one of Europe's largest industrial groups in the sector. In 2009, Rossi was acquired by the Habasit Group, becoming Rossi SPA (Group, 2014). Rossi has 900 employees and sells 150 000 gearboxes per year, with a 60 % exportation quota (Rossi, 2015). The group's logo is showed on figure 4.

Figure 4: Rossi SPA's logo.

In Italy, the group is divided into four plants, two in the Modena region, and two at Lecce (formerly part of S.M.E.I., and acquired in 2002 by Rossi SPA).

They are able to produce their own camshafts, couplings, solar Gears, pinion and satellite gears.

External suppliers preform the casting of the shell, and the quenching treatments.

Rossi produces and assembles gearboxes, like the example illustrated in figure 5.

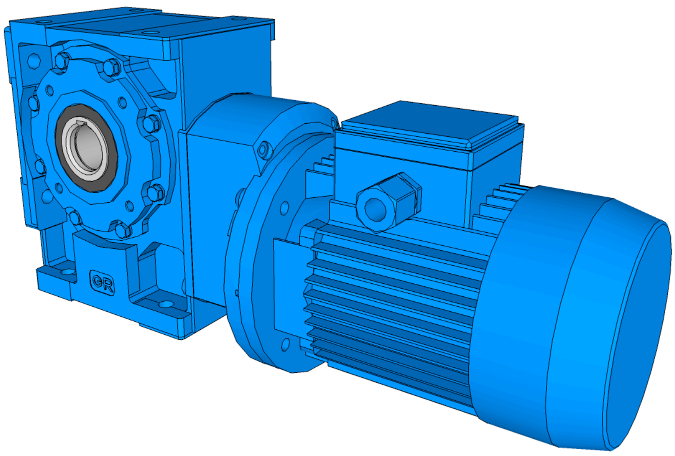


Figure 5: 3D CAD drawing of a gearbox from Rossi SPA.

Objectives of the project

Rossi SPA has been leading the conception and production of gearboxes for industrial use. With their headquarters set in Modena, they have two industrial plants at Lecce, where they produce and assembly planetary gears.

These plants, before being acquired by Rossi, were part of the former company S.M.E.I., which lived a rapid growth since the 2000's, due to their clients in the Wind Energy sector.

The recent ceasing of business with the sector of Eolic towers, has abruptly shaken their production stability and demand.

For these reasons, *Kaizen* Institute was contacted with the scope of helping Rossi SPA.:

1. Increment their turnover, through a conversion of their productive setup, allowing better delivery times and global productivity;
2. Provide training in *Kaizen* Methodology and techniques, in order to allow the company to pursue continuous improvement and convert the group into a *Lean* functional organization.

Methodology used during the project

During this project, the methodologies used include Value Stream Mapping (VSM), which allows to trace a productive process from beginning to end; Value Stream Design, used to redesign an existing process, or productive stream; Block Layout Method for layout redesign, used for the creation of productive flows inside the production plants; Single Minute Exchange of Dies (SMED), a method used to shorten the time of tool exchange; 5s, a method used for organizing and maintaining a safe, organized and productive work environment.

1.3 Scenario B – Brevini Fluid Power

Presentation of the company

Brevini is an Italian based group composed by two subgroups: Brevini Power Transmission and Brevini Fluid Power.

Brevini Fluid Power is, itself, divided into Brevini Fluid Control, Brevini Motor Pump, Brevini Power Pack and Brevini Power Gear. The Brevini Fluid Power Group has a medium annual income of 80 M €, with approximately 7 M€ of average stock, of which 2,5 M€ are obsolete, and has approximately 400 employees.

Brevini has a 4 to 8 week lead time, raw material to delivery. Brevini Fluid Power's logo can be seen on figure 6.

Figure 6: Brevini Fluid Power's Logo (Power, B. 2016).

Brevini Motor Pump produces and assembles hydraulic motors and pumps. On figure 6, a hydraulic pump is represented.

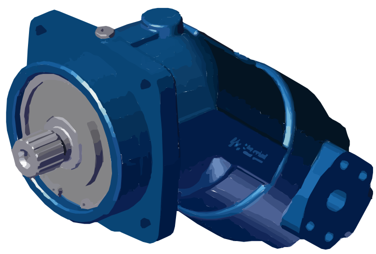


Figure 7: 3D CAD drawing of a pump produced and assembled by Brevini Fluid Power (Power, B. 2016).

In Brevini Power Pack, control units are assembled. These units can later be sold separately or already integrated in a hydraulic system. An example can be viewed on figure 8.

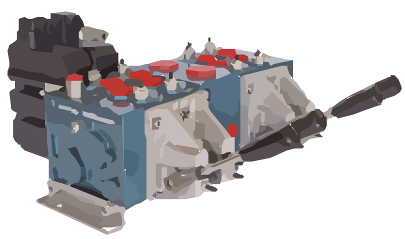


Figure 8: 3D CAD drawing of a command valve produced and assembled by Brevini Fluid Power (Power, B. 2016).

Brevini Fluid Control produces hydraulic valves, electro valves, selectors and hydraulic distributors. These components are assembled inside the "Fluid Control" plant. Before Brevini acquiring Brevini Fluid Control, the company was called Aaron, and also produced other components, being later reduced to only valves. An example of a valve may be viewed on figure 9.

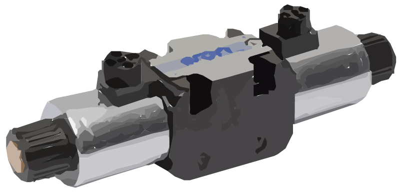


Figure 9: 3D CAD drawing of an electro valve produced and assembled by Brevini Fluid Power (Power, B. 2016).

Figure 10 illustrates the main product of Brevini Power Gear, which is in charge of assembly of hydraulic systems. These systems normally contain an electric motor, a hydraulic pump, a control unit and several valves and actuators.

Figure 10: 3D CAD drawing of a control unit produced and assembled by Brevini Fluid Power (Power, B. 2016).

Objectives of the project

The objectives of the project were to reduce the lead time by 75%, reduce operational costs, warehouse costs and improve quality.

Therefore, to guarantee a correct implementation of Total Flow Management, a Total Productive Maintenance (TPM) action was a required.

Methodologies used during the project

The methodologies used during the project included SMED, 5s and preventive maintenance tools, in the area of TPM, in the referred order.

The chosen order was intentional, in order to avoid resistance to change. In order to correctly perform SMED, the natural team will sense the need to improve their workplace organization, motivating them to accept a 5s challenge, which will also allow problems in machines and on the workstations to be spotted and corrected, thus allowing for professional maintenance sudden intervention, and establishment of new professional and autonomous standards, with periodical preventive measures.

1.4 Scenario C – Alf Group SPA

Presentation of the company

Alf Group SPA is an Italian company that dates back to the 1950's, specialized in the production of luxurious furniture. The group has been increasing its market share, investing high sums in product development. They currently employ 315 workers.

Alf produces bedroom furniture, having recently increased its scope with the introduction of living room collections.

They use as a trademark the quality and experience of their craftsman allied to a high-lifestyle range of products.

The group has its headquarters in Treviso, in the region of Veneto in Italy. The group's logo is visible on figure 11.

Figure 11: Logo of the Alf Group SPA (Group, 2016).

Alf produces furniture for the bedroom. Figure 12, shows some of the furniture they produce – beds, chests, cabinets and wardrobes.

Figure 12: Advertising photo of a bedroom line, from Alf's autumn catalogue 2016 (Group, 2016).

The group also produces furniture for the living room, (a recent expansion in production), visible on figure 13. Their catalogues include dining tables, chairs, coffee tables, cupboards, shelves and bookcases.

Figure 13: Advertising photo of a living room line, from Alf's autumn catalogue 2016 (Group, 2016).

Objectives of the project

The group contacted the *Kaizen* Institute with the objective of reducing 25% of the net worth of their stock of assembly pieces such as hinges, bolts and sliding materials, from 800 000€ to 600 000€ of merchandise in-house.

This objective was tied to a deadline of one month, with the objective of having a procedure manual to follow through with every supplier.

Methodologies used during the project

During the intervention of the *Kaizen* Institute at Alf, the methodologies used included Value Stream Mapping (VSM), Supply Chain Redesign, Kanban Supply and Kraljic's Matrix Analysis.

1.5 Structure of the document

The document is divided into 7 chapters. Chapter 1 (Introduction) aims to contextualize the consulting firm that intervened the three companies described in Scenarios A, B and C, which are also presented in this chapter.

Then, in chapter 2 (State of the Art), a summary on the best practices and methodologies used in *Lean* management is presented, delivering special focus to *Kaizen* Principles, the Toyota Production System, Total Flow Management and Total Productive Maintenance.

The third, fourth and fifth chapters focus on Scenario A, B and C, detailing the problem, initial situation and proposed solution.

The sixth chapter (Comparison between scenarios and discussion) is dedicated to the comparison of success, methodologies and limitations found in the three scenarios presented, aiming to convey the technicalities and cultural aspects that contribute to the success of the implementation of *Lean* projects. Commentaries are also present, concerning key aspects on the differences between the Scenarios, in terms of typology of product, location, market and culture.

Chapter seven (Conclusions and future perspectives) contains key points to be retained, future perspectives and suggestions, to be considered for anyone aiming to intervene in the mentioned geographical zone, industries and management field of *Lean* and continuous improvement.

Chapter 2: State of the Art

2.1 Introduction

Kaizen has been key in organizations' development over the last years. In all types of industries, including shop floors, hospital rooms and offices. It has been the very reason why in times of crisis some companies shutdown, while others prosper, developing new markets and opportunities.

Despite the broad literature found on *Kaizen*, and the ever-growing number of companies that practice *Kaizen*, misconceptions are still held, regarding the true meaning of *Kaizen* (Imai, 2012).

There are two types of change: Disruptive innovation or incremental innovation. The former, highly practiced in the west, has as an advantage a big effect on efficiency, productivity, etc. However, it demands large investments, and is very dangerous, in the sense that it cannot simply be reset. The latter, relies on small changes, over the time, naturally being less impressive, but allowing the company to manage change, iterating between small different solutions.

In practical terms, both types of innovation are important and companies should use both. Figure 14 allows us to observe a correct distribution of innovation, *Kaizen* and maintenance throughout the several levels of the workforce.

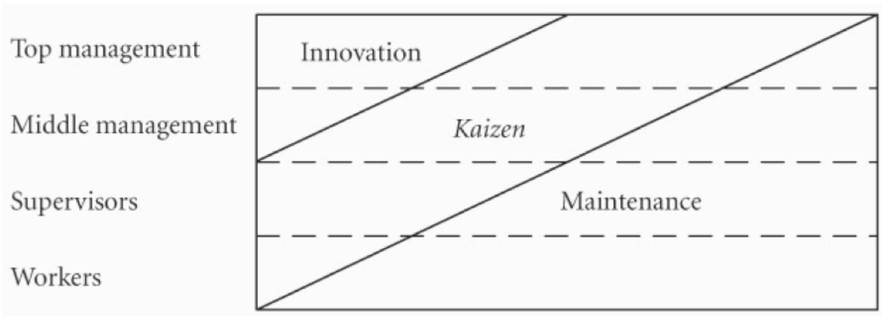


Figure 14: Improvement broken down into innovation and *Kaizen* (Imai, 2012).

Composed by two Chinese Ideograms, "Kai" and "Zen" (Figure 15) meaning, respectively, Change and Good. Therefore, *Kaizen* means, "Change for The Better" (Miller *et al*, 2014).

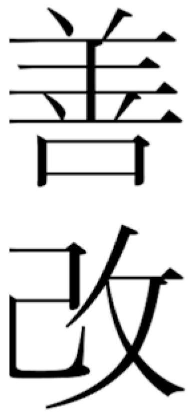


Figure 15: Ideograms that compose the word *Kaizen* (Institute, K. 2016).

Kaizen is an attitude: towards business, towards teamwork, towards life. *Kaizen* is the attitude of defying paradigms and pre-accepted solutions, challenging individuals and organizations to rethink their *modus operandi* and improve every day, everywhere, with everyone and anything. *Kaizen* is a never-ending effort to continuously improve, changing for the better, people-centered philosophy.

As can be observed on Figure 16, Kaizen activities contribute for a continuous growth of a company. The big spikes are due to "Workshops", where there is a drastic change in standards, and then a phase of stabilization, through daily kaizen activites, (Institute, 2016).

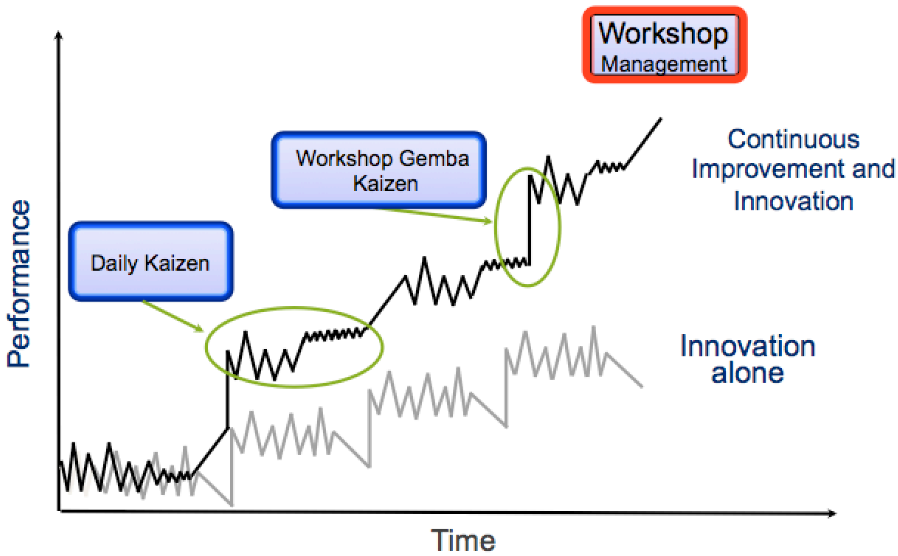


Figure 16: *Kaizen* Roadmap (Institute, 2016).

The true origin of *Kaizen* itself is generally misconceived, as normally it is traced to Japan. However, *Kaizen* was first developed in the U.S.A. firearm industry, during World War II, when, lacking human resources (that were currently employed overseas in the conflict), under the name of TWI (Training Within Industry) (Miller *et al*, 2014). This program had the goal to simplify operations, through the use of standardization, checklists and effort reduction, thus allowing women and children to preform activities that were only appropriate for men with a high skill of expertise, strength and stamina.

By the time WW II ended, TWI was brought to Japan with the scope of recovering Japan's fragile economy (Miller *et al,* 2014), where it was later developed and adapted to and by Japanese companies.

2.2 The Toyota Production System

The Toyoda Family, in the meantime, that had been developing autonomous loom machines, were ready to switch scenes and begin producing automobiles - the problem, however, was the low investment available, and the shortness of expertise. And this aspect, was the most important and relevant in the creation of the world famous TPS - Toyota Production System, not by whim, but by necessity (Ohno, 1978).

At that time, Toyota simply did not stand a chance competing with long established Ford and General Motors, if they were to copy their manufacturing philosophies. Toyota lacked the skill, the financial ease and the market strength.

For this reason, the TPS was tailored to meet Toyota's needs, based on simple, yet important details.

The TPS is built upon basic pillars, commonly being represented as structural parts of the "TPS House", visible on Figure 17. On the basis, stability of workforce, suppliers, and production. Heijunka, Standardized Work and *Kaizen* occupy the second level, being Just-In-Time and Jidoka the two pillars that hold the "ceiling": High Quality, Low Cost (for the customer) and Short Lead Time.

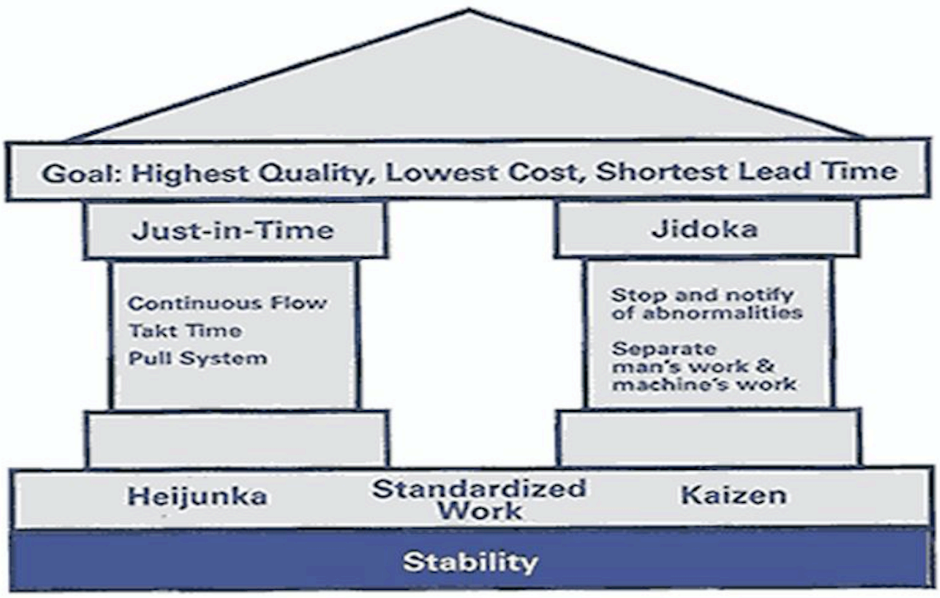


Figure 17: The Toyota Production System "House" (Ballé, 2015).

2.3 Gemba *Kaizen* Principles

2.3.1.1 The Gemba

Gemba is Japanese for “The real place” or “Where the action happens”. It can be a counter in a supermarket, an operating room in a hospital, or the shop floor of a factory. Basically, Gemba means the place where value is added, therefore it must be supported and continuously improved by everyone in the company. It is a *Kaizen* principle to always walk to the Gemba with the scope of finding the source of a problem, discovering the problem, analyzing it, and then setting measures to guarantee it shall not be repeated.

2.3.1.2 Genchi-Gembutsu

Genchi Genbutsu is a Japanese expression, which means, “To go and see for yourself, with your own eyes”. This simple principle states that, in order to understand a problem and correctly solve it, the data must be retrieved from the actual place, with the actual pieces (Imai, 2012).

2.3.1.3 The Seven Mudas

There are two types of activities: those that create value, those that do not. To the latter, Ohno called Muda, and classified them into seven types of Muda (simplified in Figure 18), common in industrial environments.

They are:

- People moving
- People waiting
- Material moving
- Material waiting
- Over-processing
- Over-production
- Defects

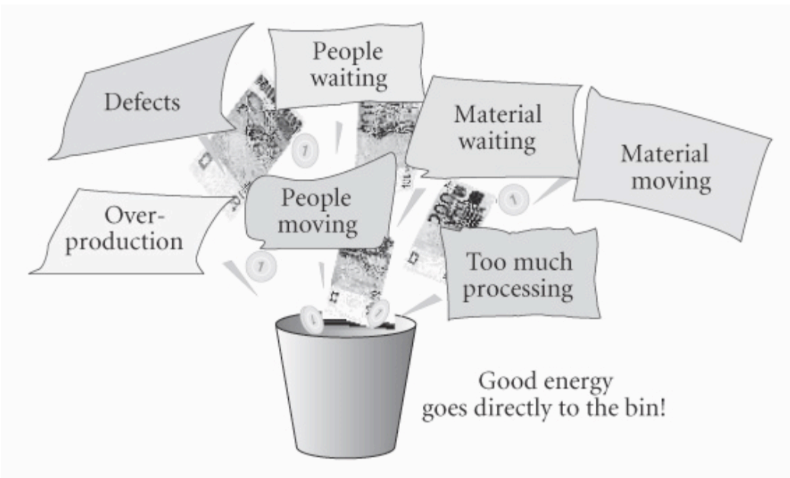


Figure 18: The Seven Mudas, according to Ohno (Coimbra, 2013).

Identifying growth opportunities may seem hard, especially when one is operating on a paradigm, believing all efforts have been conducted to improve the company and it has reached its optimum point. Until the point of "limit of the paradigm" is reached. In the sense that, unless the strategy is adapted and managed, no further improvements can be met.

A common metaphor used by *Kaizen* Institute's consultants is the example of the sailboat, where, in the paradigm that "Sails make a boat move", there's a limit to how many sails the nautical engineer can install. When this number is met, we arrive at the "limit of the paradigm", and, in order to continue improvement, a "paradigm shift" is needed, for example, leaving the sail system and converting to the engine nautical system.

Any operation that is value-adding is desired, whereas those that are not, are referred to as Muda and can be eliminated.

This list of the Seven Muda is exceptionally useful in industrial management, as it allows a company to swiftly identify waste, and correct it, by minimizing it or eliminating it. This can be done through layout redesign, process redefinition and supply chain redesign, for example.

2.3.1.4 Quality First

Although "Quality" seeks to define a standard to which a product or service should confine to, the definition itself seems to meet various versions. The American society of quality defines it as "A combination of quantitative and qualitative perspectives for which each person has his or her own definition; examples of which include, "Meeting the requirements and expectations in service or product that were committed to" and "Pursuit of optimal solutions contributing to confirmed successes, fulfilling accountabilities"" (Quality, A. 2008).

Taguchi defines it as "uniformity around a target value" (Taguchi, 1992).

The core belief to most authors is, that quality is imposed by the customer, and once set the standard objectives to be met, any deviation from them means absence quality, or, a non-conformity.

Lean companies always prioritize quality, in the sense of always satisfying the customer, meeting the agreed conditions. "Quality in a product or service is not what the supplier puts in. It is what the customer gets out and is willing to pay for" (Drucker, 1985).

All processes must be supervised in order to guarantee no deviations from the definition of quality agreed, and managing the product to be supplied.

2.3.1.5 Next Process Is the Customer

In a production flow, quality must be perceived and pursued throughout the whole process, meaning that products that do not confine to the set standard must not be passed on, nor must they be accepted.

This means the following workstation must be treated just as if it was the final customer, meaning that regardless of being an internal or external customer, quality must be assured.

2.3.1.6 Plan-do-check-act (PDCA)

The PDCA cycle is a fundamental tool in continuous improvement. The cycle comprises a planning phase in which the goals to be accomplished are set. Then, after the strategy is deployed, we must check the results in order to measure the effectiveness of the change – if we cannot measure, we cannot control and if we cannot control we cannot improve. Then, acting allows us to standardize the procedure if it was successful, reiterating or restarting the cycle if not. This cycle can be observed on Figure 19.

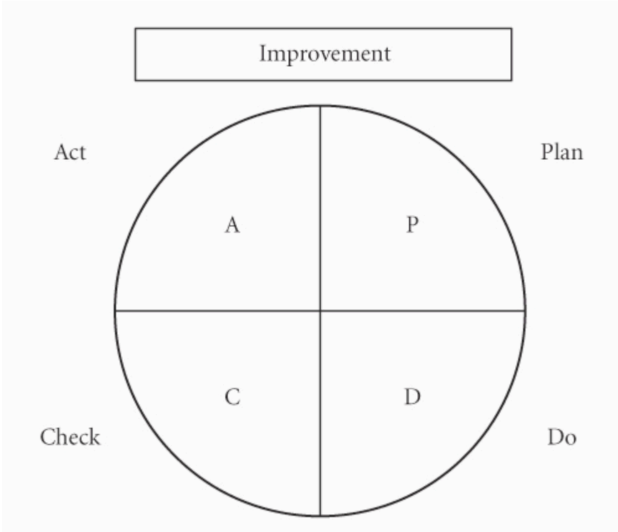


Figure 19: The Plan-do-check-act (PDCA) cycle (Imai, 2012).

2.3.1.7 Standardization

Standardization is a crucial step in creating a *Lean Kaizen* culture. Standardization allows organizations to minimize and avoid variation, creating predictable results to their processes and products. Standardization can be regarded as "The best known way to do something" (Imai, 2012). Standards must not be static and should evolve over time, as new methodologies and improvements are met.

2.4 Total Flow Management

Developed by *Kaizen* Institute, the TFM Model, aims to design any company's supply chain reducing lead time, increasing quality and controlling costs through the creation of a production flow, creating long term value. Like the TPS Model, the TFM it is based on simple premises that allow products to flow through the processing steps from customer order until customer delivery.

As can be observed in Figure 20, basic stability is a must in order to create a production flow, which itself is essential for creating Internal Logistics Flow and External Logistics Flow. To combine these four pillars, Supply Chain Design is needed in order to organize any corporation into a *Lean*, *Kaizen* practicing organization. Usually the reference to create basic stability are the 4M's - consisting of Manpower (steady teams, with no absenteeism, strikes, etc.), Machine reliability (No machine breakdowns or down time, guaranteeing efficient production), Material (Continuous material availability and readiness) and Method reliability.

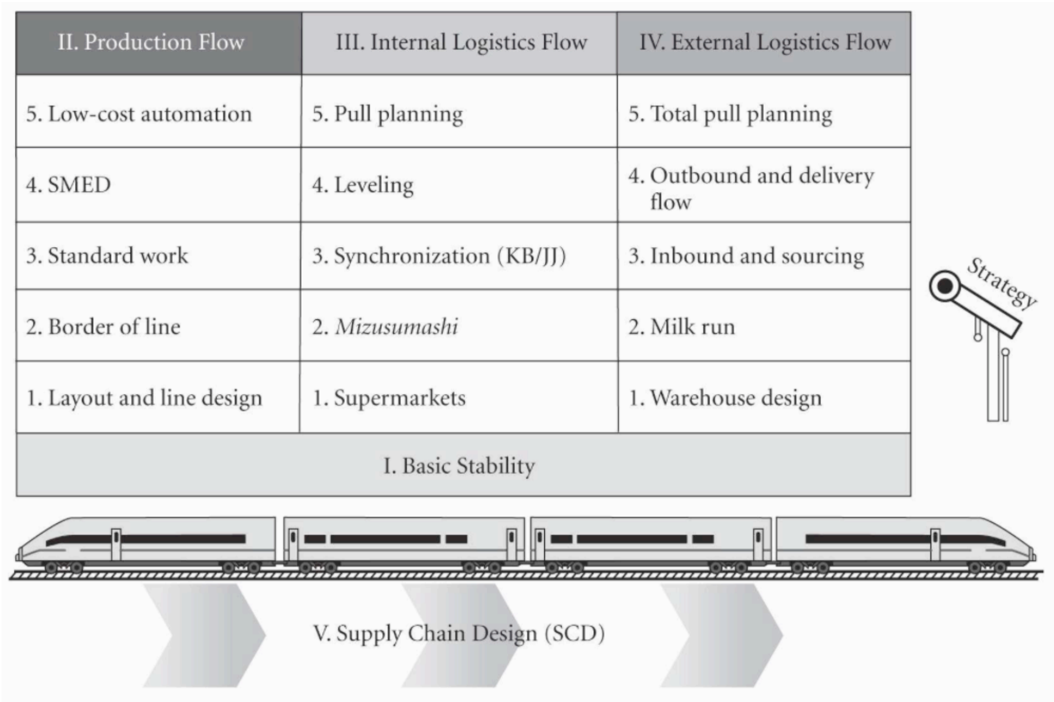


Figure 20: The TFM Model (Coimbra, 2013).

Production Flow is constituted by layout and line design (reducing material and people traveling time), border of line (correct feeding of materials, tool placement and stocking areas) that minimize waste, standard work (the best known way to perform an operation), SMED (Single Minute Exchange of Dies, developed by Shineo Shingo during his stay at Toyota, where he successfully changed 12-hour exchanges of heavy dies into 9 minutes or less operations) and Low-cost automation.

Internal Logistics Flow refers to all the materials, WIP and people in movement inside the Gemba

It is achieved by the means of:

- Supermarkets (points of stock, with low quantities of varied products which enable easy and fast picking, demanding periodically-short replenishments, set on ground level);
- Mizusumashi (Logistic trains, with synchronized times of transport and picking on fixed routes, whose goal is to continuously feed the lines with the raw materials and semi-products necessary);
- Synchronization (either Kanban or junjo, which are signal cards that tell the Mizusumashi driver when to move from the supermarkets to the lines, enabling a pull system);
- Leveling (which refers to a balanced distribution of work charge in cells, operators, etc.) and Pull Planning (producing according to customer needs instead of a production forecast).

The External Logistics Flow is guaranteed by:

- Correct warehouse design, arranging milk runs (with either the suppliers, or with other companies who supply the same customer, reducing logistic investment and waste);
- Inbound and sourcing;

- Outbound;
- Delivery flow;
- Total pull planning.

2.5 SMED

SMED is a Setup reduction process that consists of 5 steps, represented on figure 21. The main goal of SMED is to reduce the time a machine is stopped to a minimum, in other words, not producing.

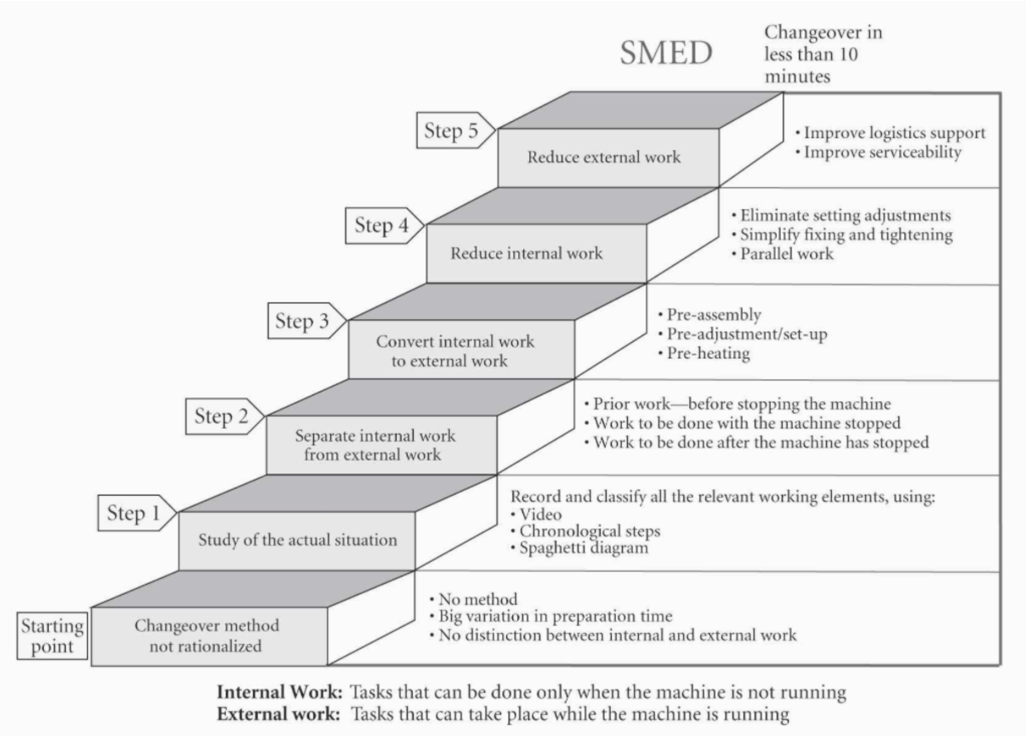


Figure 21: The SMED process (Coimbra, 2013).

The first step, incites us to classify operations in either Internal or External operations. Internal operations are tasks that can only be performed when the machine is stopped (for example, removing cutting tools), whereas External operations are tasks that can be performed when the machine is operating (for example, fetching a screwdriver)..

In the second step, Internal operations must be grouped, changing the order of the process – External operations must be performed either before the machine is stopped, or after the machine has restarted.

The third step consists on converting Internal work into External work (for example, setting up features of the machine before stopping the machine and inserting them, proceeding later to screwing or bolting).

Step four consists on reducing Internal operations (this can be achieved by simplification of the mechanic setup of the machine, or conversion to a fast-bolting system for example).

Step five consists on reduction of External operations (for example, improving cleaning methods or storing procedures) (Coimbra, 2013).

A visual example can be viewed on figure 22, of a SMED process applied to a generic Scenario.

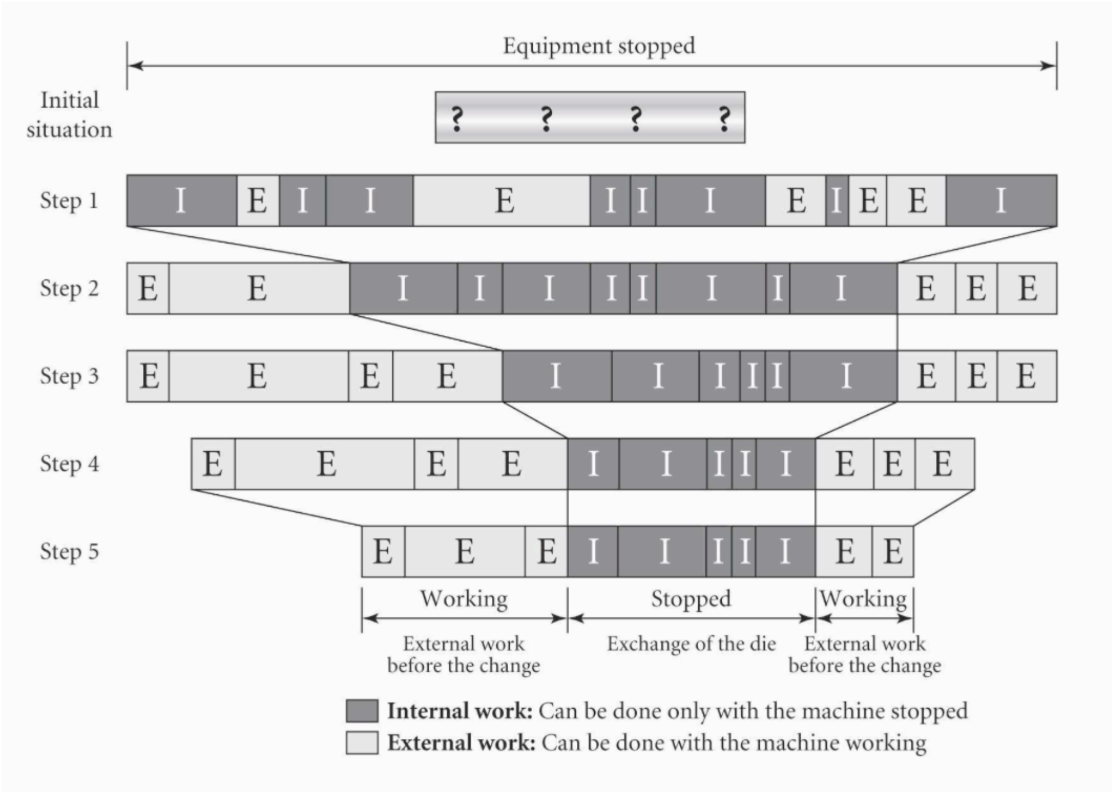


Figure 22: Example of an applied SMED process(Coimbra, 2013).

In order to perform a SMED process, it is normally required to have video footage of a previous setup, a spaghetti chart (tracing of the operator's movements against the layout of the workstation) and a list of operation and corresponding times. These elements are useful during the analysis of the process and are key to correct decision taking.

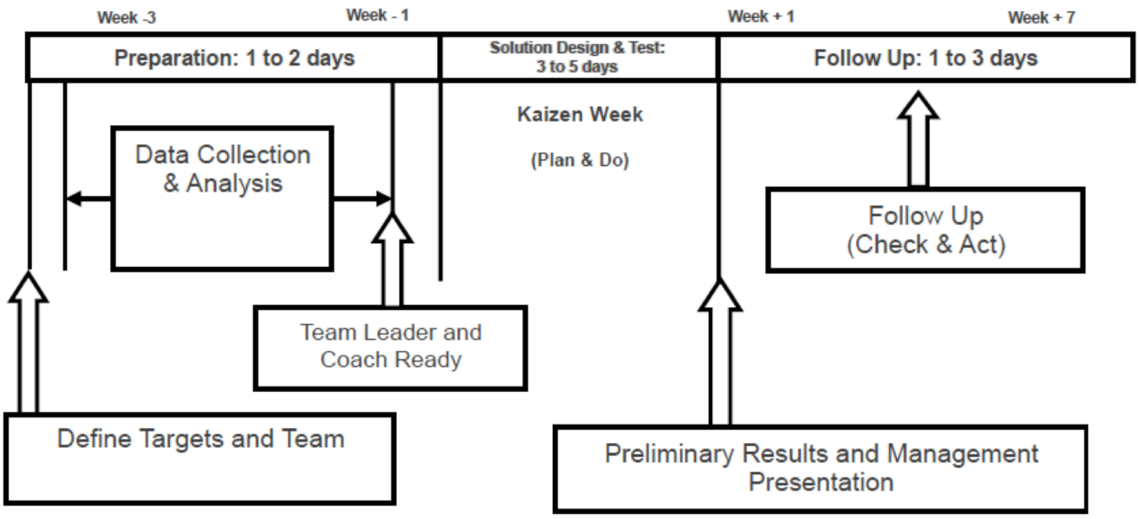


Figure 23: SMED Gemba *Kaizen* Workshop agenda (Institute, 2016).

From figure 23, shows the typical agenda for a SMED workshop. This agenda allows to prepare correctly the workshop, perform it and manage it, and posteriorly act. The Preparation and Follow Up are essential to guarantee a correct implementation (Institute, 2016).

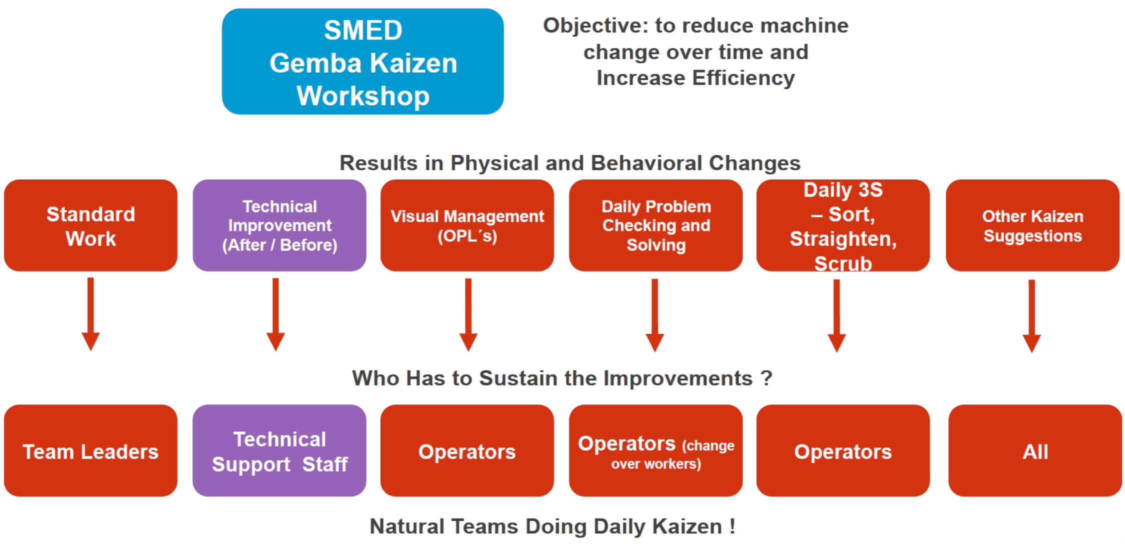


Figure 24: SMED Gemba *Kaizen* Workshop (Institute, 2016).

Figure 24 sums up the the expected results and behavioral changes after a SMED workshop. These changes, must be followed by different team members, in order to guarantee a successful implementation. Team leaders are responsible for supervising and approving the new standard work, the maintenance members are in charge of machine alterations, Operators are responsible for creating Visual Management elements and constantly bring up problems and propose better solutions and improvements, and to maintain the 3 first steps of the 5s program initiated (Institute, 2016).

2.6 The 5S

"The *Kaizen* principle of 5s stands for five Japanese words that constitute good workplace organization" (Imai, 2013).

These 5 words are:

1. *Seiri* (Sort) - Decide what is necessary and what is not;
2. *Seiton* (Set in order) – Set in order the remaining objects after Seiri;
3. *Seiso* (Shine) - Keep materials, workbenches and machines clean (through manual cleaning, inspection can be done, thus contributing for the maintenance of machines);
4. *Seiketsu* (Standardize) - Standardize the preceding steps and extend to rest of the organization;
5. *Shitsuke* (Sustain) - Systemize habits of cleaning and keeping in order (Imai, 2013).

The 5s aim at creating a safe, clean and organized work environment, where only what is needed should be available – this allows the operator to swiftly change tools without losing time searching or deciding. Having a clear workbench enables an ergonomic working position. A clean work environment also allows management to spot inefficiencies, problems and thus, continuously improve.

Through the process of manually cleaning the machines, the operators can inspect them, preventing shutdowns, and contributing to a correct maintenance.

The 5s have been thoroughly studied and applied, and are not exclusive to industry, as can be seen in the example of the Seki Chuo Hospital in Japan. Leading worldwide medical centers, Seki Chuo did a slight change to the 5s method, substituting the 5th s, Shitsuke or Sustain, for

"Smile". This positive reinforcement allowed sustaining to be an initiative of each employee, being a big incentive to good house-keeping (Fabiano, 2016).

2.7 Value Stream Mapping and Value Stream Design

"A value stream is all the actions (both value added and non-value added) currently required to bring a product through the main flows essential to every product" (Rother and Shook, 1999).

Value stream mapping is a tool used in *Lean* management to convey information about a supply chain, or about a process flow, allowing thorough analysis on waste and its sources.

It concentrates *Lean* techniques, allowing a quick and broaden understanding of an industrial flow, forming the basis for an implementation plan or project.

This tool allows analysis on lead time, cycle time, amounts of inventory and distinction between added value and non-added value activities (Rother and Shook, 1999).

Figure 25 shows an example of a value stream of a supply chain.

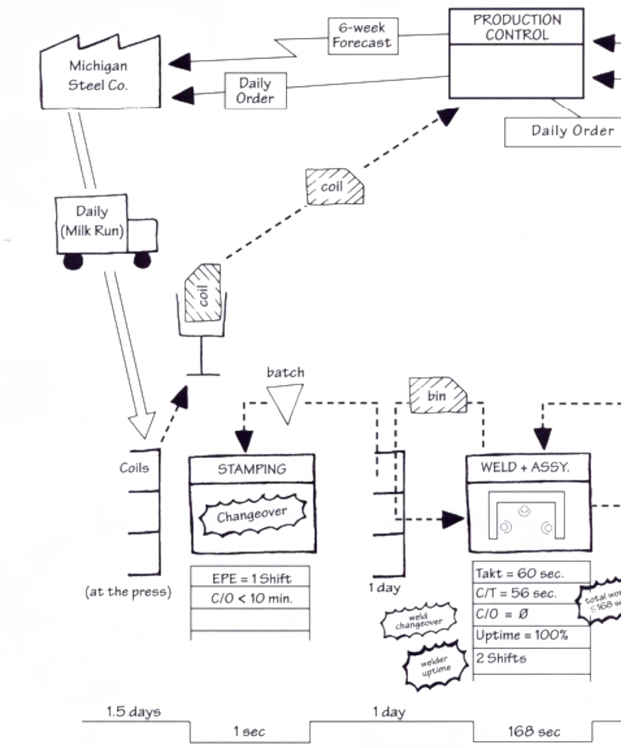


Figure 25: Future state Value Stream of ACME (Rother and Shook, 1999)

Tracing the Value Stream Map of processes is also extremely useful when implementing a *Lean* project. For the effect, a code of symbols is used to simplify collection of data and information:

- Circle – represents transformation, value added;
- Triangle – represents stock, WIP, material waiting;
- Square – represents quality control, decisions;
- Arrow – represents transport, movement.

An example of a template for VSM data collection can be viewed on figure 26. This simple table allows fast collection of data and analysis.

KAIZEN INSTITUTE **Value Stream Mapping**

Famiglia di prodotto		Takt Pz/gg		○	Trasformazione
SKU		Regularity / quantity map		□	Controllo
Main subassembly		Data		▽	Stock/Attesa
Main component		Pagina		⇨	Trasporto/Trasferimento

N°	Descrizione	Simboli				Dati				Note
		○	□	▽	⇨	Tempo	Quantità	Distanza	Superficie	
	Totale									

Figure 26: Template sheet for VSM data collection. (Institute, 2013)

2.8 Total Productive Maintenance

According to Imai, 70% of machine breakdowns are due to low levels of oil, water and existence of dirt (Imai, 2012). This is an impressive figure, which clearly indicates that most of the problems generally found in equipment are due to the lack of preventive measures and maintenance.

Figure 27 shows the "House of TPM", where the main topics are represented as cornerstones.

Kobetsu Kaizen refers to quality maintenance, Autonomous Maintenance refers to activities performed by operators, Planned Maintenance refers to preventive and professional Maintenance, Teaching and Training refers to people involvement and development – in terms of maintenance, operation and skill.

Early Equipment Management, consists on "a systematic analysis around key decision milestones to avoid the transfer of problems to later steps" in maintenance management (McCarthy, 2014).

Quality Maintenance has the goal of guaranteeing zero defects, by understanding and manipulating the 4M's, essential for reliability (Man, Material, Machine and Method), reducing cost, rework and control.

Safety and Environment concerns the correct management of industrial waste and work safety, whereas "*Kaizen* in the Office" refers to optimization of information centers, reducing the time needed to withdraw information.

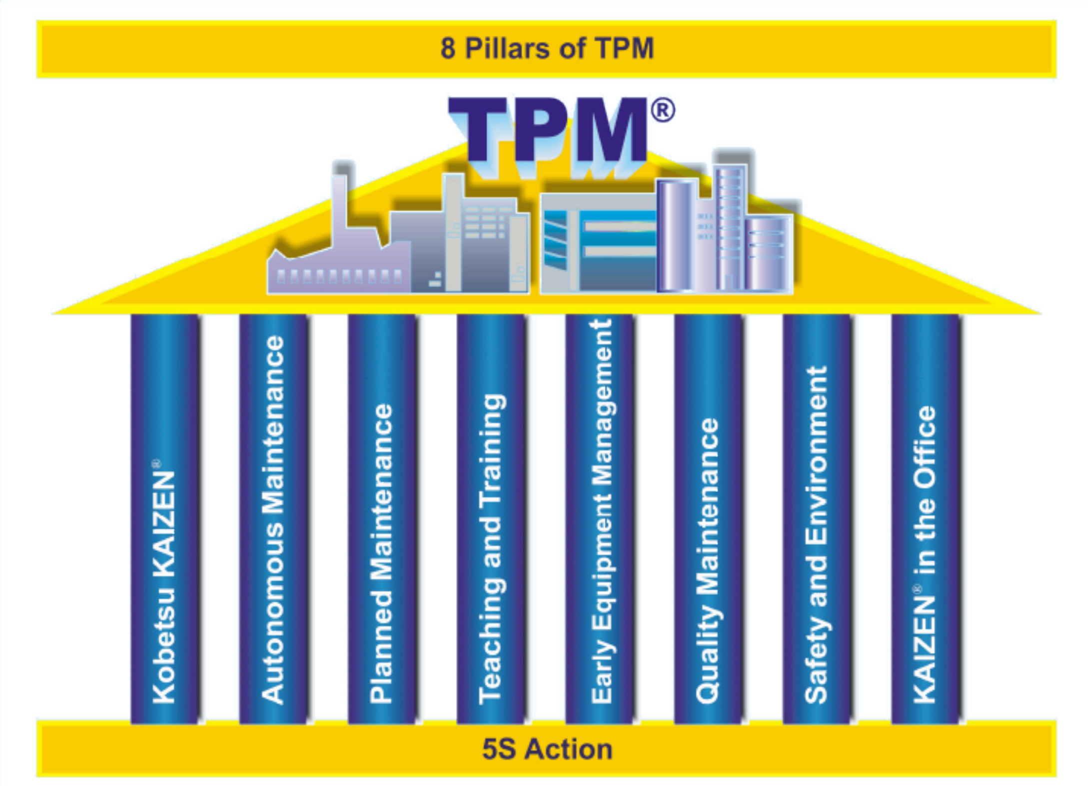


Figure 27: The house of TPM (Institute, 2016).

The existence of a well-defined maintenance program is crucial for the performance of any company. These programs exist in the form of Professional Maintenance (performed by a dedicated team from the company, or outsourced) and Autonomous Maintenance (performed by the operator).

An intervention can be preventive or corrective – the former before problems arise (when machine shutdown is necessary). The latter, after anomalies have been detected (and the machine has been shut down).

Creating these programs is not always an easy task. Most maintenance teams are over-working, solving many problems inside a productive plant (most of these problems due to lack of Total Productive Maintenance), and most of the tasks necessary for preventive maintenance are not carried out.

Identifying the elements in need of maintenance, the root causes and the frequency of maintenance can also be a hard job, due to problems of accepting responsibility, or taking charge for the occurrence. For this reason, a method commonly used is the "Red Card" signaling (visible on figure 28), where a team will place a red card in any spot of a workstation requiring maintenance – be it professional, autonomous, periodical or spontaneous.

Figure 28: "Cartellino Rosso", card used for signaling problems in a workstation, for posterior analysis and scheduling of maintenance (Institute, 2016).

The red card method allows analytical, emotional-detached analysis, where the objective is to read the card, sort out the root problem, and create measures to avoid its recurrence.

2.9 Conclusions of the chapter

During the implementation of Total Flow Management, the sequence of priorities to be followed should always be FSL – Flow, Synchronization, Levelling.

This means, that the main focus in the beginning of any TFM project should be to guarantee a continuous, laminar flow in production.

In order to guarantee this, the 4M's (Man, Method, Material and Machine) reliability must be attended.

Total Productive Maintenance allows material, method and machine smoothness in the productive process, guaranteeing parts arrive on time, as expected. In order to do this, productive lines must be flexible, work in small batches (which implies quick setups and tool-changes), without breakdowns or malfunctions. Defects must be brought to a minimum, or most preferably, eliminated.

To implement all of these requirements, a *Kaizen* culture is needed, with optimism to approach problems and improve quality, delivery and cost every day. With the basic concepts approached in this chapter, it is possible to shape an existing culture and initiate a *Lean* journey for any company.

Chapter 3: Scenario A – Implementation of Total Productive Maintenance in a Gearbox production supply chain

3.1 Introduction

Rossi SPA is present at the city of Lecce, South Italy, producing planetary gearboxes. The supply chain is constituted by a production factory, Lecce 2, and an assembly plant, Lecce 1.

During *Kaizen* Institute's intervention, it was decided to intervene on pilot projects, extending them to the rest of the organization once improvements were stabilized and confirmed.

3.2 Initial situation

Rossi was being intervened by *Kaizen* Institute with the scope of implementing Total Flow Management.

The plant had no flow, the workstations had huge amounts of WIP piled up, with no decent storage areas, as can be seen on Figure 29.

Figure 29: Photo of WIP in Lecce 2's shop floor, where quantities of WIP, absence of standard and disorganization are visible, August 2016.

Lead time was approximately 25 days in fast lines, and up to 60 days for medium and slow moving lines.

The workstations also were employing more operators than necessary due to unclear work standard, and to the lack of correct line design. A reduction in the order of 50% was necessary, to ease the financial responsibility of the company.

The workstations were very disorganized, occupying areas up to four times the necessary. WIP laying around, raw materials randomly placed and disorganized work benches were a problem, as can be viewed on figure 30.

Figure 30: Photo of one of Rossi's workstations, where disorganization and lack of standards are visible, at Lecce 2, August 2016.

A Total Productive Maintenance program was sought fit to solve issues concerning the machines and workstations, in order to guarantee a stable supply of finished pieces and quality.

The workbenches' organization needed improvements (evidence on figure 31), having more tools than needed, personal belongings displayed on the bench, measurement instruments out of their protection boxes and drawers filled with carton and old job instructions.

Machine break-downs weren't acknowledged or documented and setup times were long (approximately 4 to 6h).

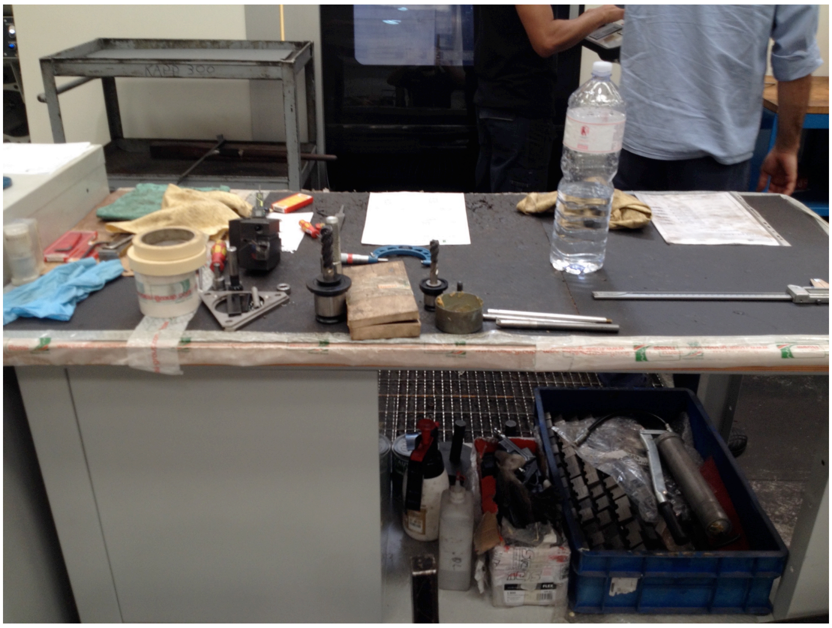


Figure 31: Workstation at Rossi before the intervention of *Kaizen* Institute, August 2016.

Figure 32 represents the functioning state of the Lathe workstation flow, being clear it is a bottleneck, and showing the lot-size, of 150 pieces per batch, with no flow. It also shows the MRP functioning system, were the station is informed, based on predictions, how much pieces are to be produced.

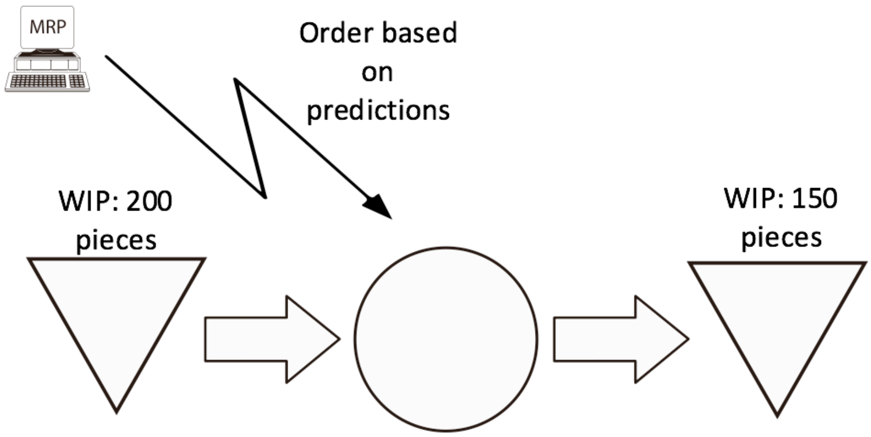


Figure 32: VSM of the DMG CTX 800 (CNC Lathe) workstation.

WIP is stored in areas far from the workstation, which compromises flow and generates Muda.

3.3 Proposed solution

To guarantee machine reliability, a VSD was conducted, changing the ordering system, reducing lot size and redesigning the layout. Figure 33 shows the new Value Stream, where smaller batches are visible, with semi-product supermarkets before and after. The flow is supposed to only be started by placing a withdrawal kanban. Once a specified quantity is consumed, a production Kanban is sent to the workstation, which then should send a withdrawal Kanban to the preceding semi-product (one processed step less). The workstation should now work in smaller batches, but in order to do so, changeover times must be severely reduced. The batches needed to be reduced by one third in size.

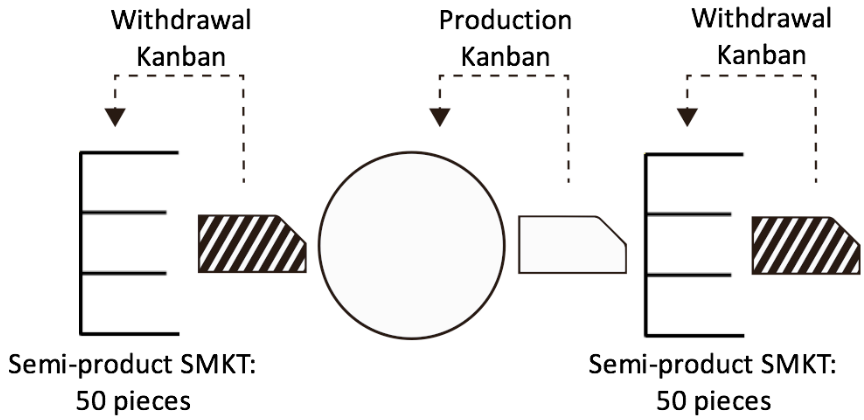


Figure 33: VSD of the DMG CTX 800 (CNC Lathe) workstation.

The TPM project was deployed with a SMED activity in one of the critical machines in terms of setup.

After SMED, a 5s initiative followed, being proposed a maintenance program review. In the Scenario presented, only SMED and 5s were carried out, due to a premature ending of *Kaizen* Institute's intervention.

Upon arrival, a study on the setups performed on a DMG CTX 800 (CNC Lathe) was carried. The objective was to understand the tool-changes performed in the previous months and its durations. These results can be viewed on figure 32.

	90030103	90000105	90000102	90030103	908620	90030134	50060109	50040102	50150102	50030102	50090102	50120102	50020102	50010102	50000102	50150102	5015012
90030103		5,65															
90000105			4,5				4,5										
90000102				7,5													
90030103					0,17												
908620						9,9											
90030134		4,45															
50060109								0,8									
50040102									0,11								
50150102										0,16 / 4,9							
50030102									0?		4						
50090102												0,03					
50120102													7,67	1,35			
50020102														1,75			
50010102													0?		6,13 / 0,85		
50000102														0?		12,01	
50150102																	8,2
50040102																	

Figure 34: Map of setup duration (in hours) between different SKU's, before SMED from the months of July and August 2016.

It is clear from figure 34 that setups had a lot of variability and some exchanges were unacceptably long.

In order to simplify the analysis, the different codes of products were grouped into G1, A1, G2 and A2, representing the significant differences in tool-change. A stands for “Albero” (Italian for camshaft), G stands for “Giunto” (Italian for coupling) and 1 stands for less than 85 mm in diameter, and 2 for more than 85 mm in diameter. This new arrangement can be observed on figure 35.

	G1 (<85mm)	A1 (<85mm)	G2 (>85mm)	A2 (>85mm)
G1 (<85mm)	1,5h	4,5h	3,0h	6,0h
A1 (<85mm)	4,5h	1,5h		
G2 (>85mm)	3,0h		1,5h	
A2 (>85mm)	6,0h			1,5h

Figure 35: Simplified matrix of tool change, with old setup times, before SMED.

This simplified analysis allowed understanding on the variables of the tool-change, being clear that between G1 and A1 or G1 and G2, a substitution of mandrel was performed (a very complicated substitution due to the weight and dimension of the mandrel, being necessary the use of a crane).

Figure 36: Footage of a tool change at Rossi SPA at Lecce 2, filmed September 2016.

The first step was to collect information on the actual performance of tool change. Video footages (figure 36) were collected for posterior analysis in the workshop, of a tool-change without mandrel substitution. The initial time was of 270 min (4 h and 30 min). Spaghetti Charts and List of operations were also collected.

The second step was to discuss the tool-change in a workshop environment, with a multi-disciplinary team (figure 37). In this workshop, the video was watched with a 2.0 speed, in order to detect Muda and opportunities of improvement.

Figure 37: SMED Workshop, September 2016.

After discussion, a new standard was produced, being visible on figure 38. This new standard now contained operations conveniently divided and classified into external and internal, being de latter isolated, reducing stopped time.

Figure 38: Checklist of operations for tool-change, created during SMED workshop, September 2016.

Upon testing and reiteration, the standard was updated, typewritten (figure 39), and shared with all of the team members. It was also decided to produce a checklist for tools to be introduced during the setup.

CICLO SET-UP: *Da Albero (A) a Giunto (B)*

CAMBIO N°

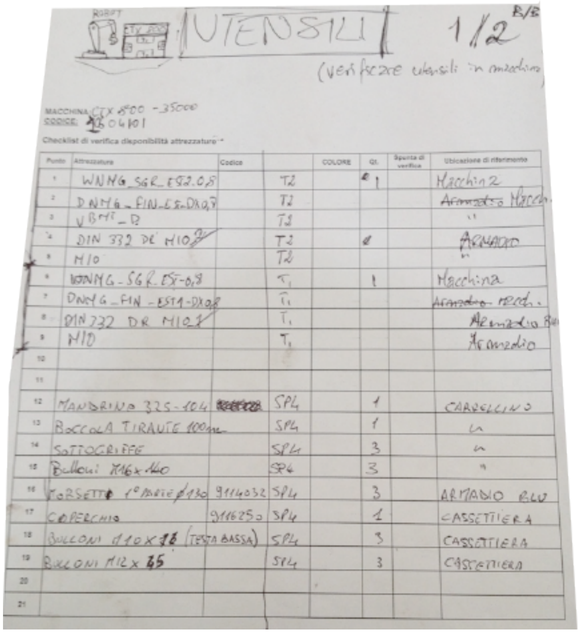
Operatori: 1 - Meccanico1; 2 - Aiuto meccanico1

Data:

N° Fasi	MACROFASE (DESCRIZIONE)	OPERAZIONI (DESCRIZIONE)	TEMPO 1° Cambio [minuti]	TEMPO NUOVO PREVISTO (2° cambio) [minuti]	TEMPO PER FASE [minuti]	TIPO SETUP INT	TIPO SETUP EST	UTENSILI UTILIZZATI	N° ELEMENTI	NOTE
	Preparazione lavoro	Controllo check- list utensili manuali					x			
		Preparazione attrezzature particolare B vedi check-list					x	check-list		
		Preparazione strumenti di controllo					x	strumenti controllo		
	Preparazione materiale grezzo (B)	Sistemazione a bordo macchina					x	pz/barra grezzi		
	Attrezzamento mandrino 1	Blocco Mandrino				x				
		svitare 6 viti				x				
		sostituzione pinza elastica e boccola interna	9:40	6:00		x		pinza/boccola		
		serraggio 6 viti				x				
		prova movimento serraggio mandrino 1				x				
	Attrezzamento mandrino 2	Blocco Mandrino				x				
		sostituzione rapida griffe particolare B	10:00	3:00		x		Griffe montate su sotto-griffa		
		Controllo concentricità				x				
	Attrezzaggio torrette 1 e 2	Posizionamento a quota fissa delle torrette	22:00	12:00		x		check-list		
		montaggio/sostituzione portautensili secondo check-list				x		portautensili		
	Programmazione e richiamo NC	Dichiarazione posizioni utensili su torrette	12:00	12:00		x		check-list		
		controllo programma secondo check-list				x				
	Attrezzaggio spingibarra	Preparazione e carico prima barra	12:00	12:00						
	Tornitura 1° pezzo	Lavorazione lenta con controlli manuali secondo piano di controllo	38:00	(38:00)		x		piano di controllo		
		Eventuali correzioni usure utensili secondo piano di controllo				x		strumenti dichiarati nel piano		
	Attrezzaggio Robot	Regolazioni griffe con pezzo campione in attesa	8:00	8:00			x			
		del pezzo di collaudo					x			
		TOTALE	111:40	29:00						
	Controllo 1° pezzo	Controllo quote secondo piano di controllo					x			
		Controllo visivo					x			

Figure 39: List of operations for tool-change, after SMED, definitive version, September, 2016.

It was also decided to produce a checklist for tools to be introduced during the setup (figure 40). This last step was done with a big involvement of the operators, which resulted being a quick and efficient task.



UTENSILI 1/2 B/B

(verificare utensili in macchina)

MACCHINA: CTX 800 - 35000

CODICE: 04101

Checklist di verifica disponibilità attrezzature *

Punto	Attrezzature	Codice		COLORE	Qt.	Spunta di verifica	Ubicazione di riferimento
1	WNMG_SGR_ES2.0,8		T2		1		Macchina 2
2	DNMG_FIN_ES_DX0,8		T2				~~Armadio~~ Macch.
3	VBMT_D		T2				"
4	DIN 332 DE M10		T2				ARMADIO
5	M10		T2				"
6	WNMG_SGR_ES-0,8		T1		1		Macchina
7	DNMG_FIN_ES1-DX0,8		T1				~~Armadio~~ mech.
8	DIN 732 DR M10		T1				Armadio Blu
9	M10		T1				Armadio
10							
11							
12	MANDRINO 325-104	[illegible]	SP4		1		CARRELLINO
13	BOCCOLA TIRANTE 100mm		SP4		1		"
14	SOTTOGRIFFE		SP4		3		"
15	Bulloni M16x140		SP4		3		"
16	CORSETTO 1° PARTE Ø130	9114032	SP4		3		ARMADIO BLU
17	COPERCHIO	9116250	SP4		1		CASSETTIERA
18	BULLONI Ø10X16 (TESTA BASSA)		SP4		3		CASSETTIERA
19	BULLONI M12x35		SP4		3		CASSETTIERA
20							
21							

Figure 40: Checklist of machine tools, for setup, after SMED, September 2016.

After producing the necessary guidelines and check lists, a tool trolley was prototyped, carrying the essential materials to perform the Setup (figure 41). The decision of creating a tool-trolley came from the analysis of the spaghetti chart, which showed long distances covered by the operator, due to poor layout and lack of good house-keeping.

By consulting the tool-checklist, the operator could search the required materials in the cabinet, place them on the trolley, and then proceed to setup the machine, reducing traveling time and distance.

Figure 41: Prototype of Tool Trolley, for use during tool-change, after SMED, September 2016.

From the video footage and discussion with the operators, it was understood that carrying the tools inside the machine was not very ergonomic, and they physically suffered with the effort. So, a prototype of a toolholder box was conceived to allow filling and then positioning inside the machine. This toolholder is visible on figure 41 and 42 (yellow box with wood appendixes).

On figure 37, the toolholder can be observed in its position. It is meant to be used only when the machine is shutdown, allowing swifter picking and placing of tools.

Figure 42: Prototype of “Tool Box” with adaptor for tool-change, after SMED, September 2016.

The measures taken allowed to reduce an initial setup of 270 min to 140 min, representing a reduction of 48,1%.

Further reductions were possible, for example, by performing the setup with two people, in parallel. (An operator for the programming of the automatic robot, and programming of the lathe, 60 min; and an operator for the tool-change on the lathe, 80 min).

The next phase of the TPM project was to carry out a 5s program. The team had already noticed that in order to perform well the reduced-time setup, the workstation should be lean and organized, allowing quick movements, quick decisions and reduce time searching for tools and materials.

On figure 43, the transformation process in the Gemba can be observed. It was chosen to involve engineers in the change of scenario, as an incentive to the operators. By involving everyone, all the effort was shared and a feeling of common goal was achieved.

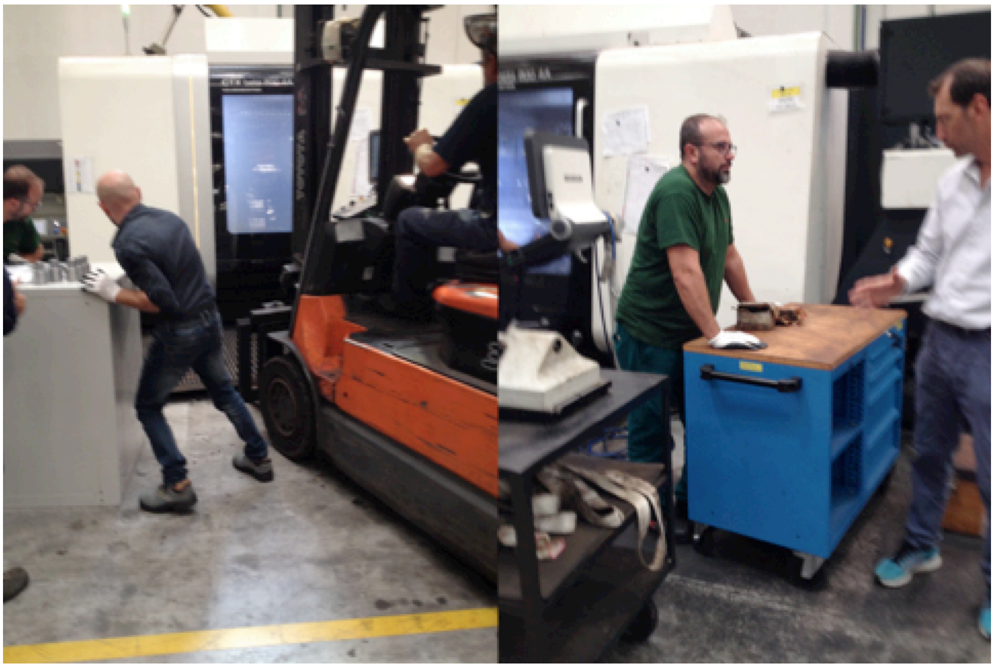


Figure 43: Photos during initial 5s project, reorganizing the workstation.

Figures 44 and 45 show comparison between the "Before" and "After" 5s effort, clearly showing the differences in security, cleanliness and organization.

Figure 44: Before 5s, August 2016; and After 5s, September 2016.

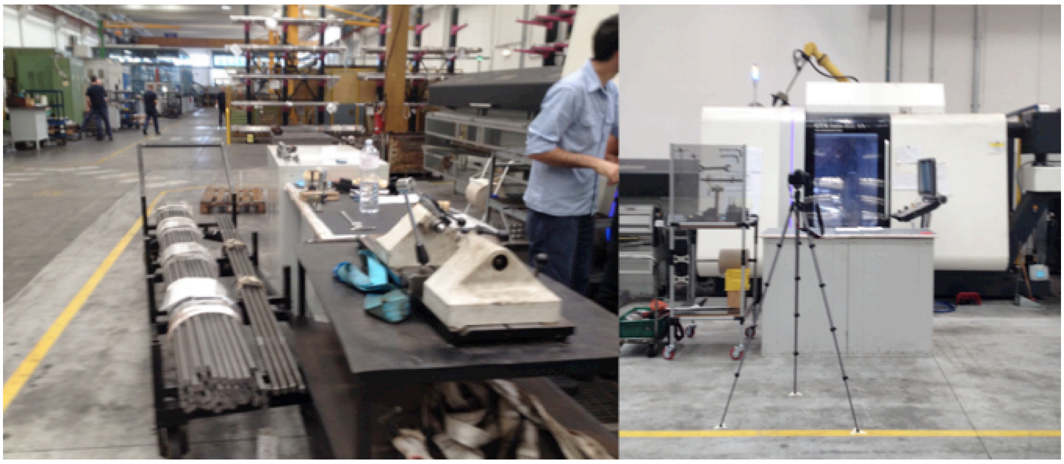


Figure 45: Before 5s, August 2016; and After 5s, September 2016.

3.4 Commentaries

The project presented in Scenario A came to a premature end, due to the company's lack of financial ease.

For this reason, the normal procedure to follow, when implementing TPM, was cut short. No maintenance programs were created or updated.

One of the most compromising aspects during the project was that Rossi was undertaking an Italian Governmental Industrial Financial Incentive, concerning companies in crisis: "Cassa Integrazione": When companies do not have enough cash flow to operate, and to "turn on" the factory every day, they select a few days each month to work. When the plant operates, each worker receives 100% of their income, corresponding to a full work day. When the plant is closed, workers receive 70% of their income, while remaining at home. 35% is paid by the company, while the remaining 35% are paid by the Italian state. Demands from the government to check on improvement and measures to escape the crisis are not clear, which ends up to be a poor incentive for worker's commitment to improve productivity levels and their company's financial health.

3.5 Implementation results

During this project, the main milestones achieved were Setup reduction to 48,1%. It was a good result, however, more iterations are need to achieve better performance and reduction of costs. The 5s action brought a big improvement to the workstation, and operator's satisfaction was clear.

The SMED action brought a total annual saving of 25 389 €. This result can be seen on figure 46.

Result of SMED at Rossi	
Cost of Setup (€/h)	**90**
Setup Time Before (h)	**4,5**
Setup Time After (h)	**2,33**
Time Saved (h)	**2,17**
Money Saved Per Setup (€)	**195,3**
Number of Setups / Year	**130**
Yearly Savings (€)	**25389**

Figure 46: Savings achieved at Rossi after SMED.

The result obtained after the first SMED workshop was very positive, and a contributing factor was the involvement of the operators.

Firstly, they denied any improvement could be done, but by showing them the video footages, they were able to see the *Muda* in the process, and were absolutely determined to overcome them.

Without involving the operators, such a result would never be achieved on the first iteration. Reducing the setup time is, of course, a continuous effort, and should not be left at this point, being that the only analyzed steps were classification into internal and external tasks, grouping of internal tasks and internal tasks reduction. A long way in the *Lean* journey still lies ahead for Rossi.

Chapter 4: Scenario B – Implementation of Total Productive Maintenance in a hydraulic component production supply chain

4.1 Introduction

Brevini Group is an Italy based company leader in power transmission industry, owning 3% of global market share with 320M € of Annual Revenue.

Brevini produces more than 10 000 customized items, with a “order to delivery” time process 4 weeks long.

They had, at the start of the project, 40M € of inventory (4 000 square feet's occupied by the authomatic warehouse) and owned all process steps, from machinery (component production) to assembly line, with the exception of heat treatments and foundry. The manufacturing process addresses up to five different plants.

Brevini Fluid Power, who had an annual income of 80 M€, with 7 M€ in stock, contacted *Kaizen* Institute with the scope of redefining their productive flow and competitiveness in terms of cost and delivery. Their productive plants suffered with the absence of flow and with and low machine reliability.

Top management realized the group was lacking three major competitive edges, being cost, quality and delivery.

4.2 Initial situation

After analyzing the productive areas of the Brevini Fluid Power Group, it was clear that the main source of problems and obstacles at a productive level was the complete absence of flow.

The absence of productive flow was due to a poorly designed layout, unclear vision of product families and their representativeness to the company’s revenue, absence of workstation organization, cleanliness and excess of materials and tools.

The company’s financial health suffered also due to excess of inventory in warehouse and in-house, having high levels of WIP and producing very big batches.

The group was also dealing with approximately 7 M€ of obsolete products in stock, with absolutely no chance of getting around these unsellable merchandise.

Brevini Fluid Power was initially constituted by six plants, of which three for assembly purposes (Motor pumps, valve, control units), two for production of components, and the latter for expedition.

One of the biggest issues was the lack of metrics. The only measures that concerned management were “Revenue” and “Service Level” (Ratio between “how much was delivered” and "How much was demanded"). There was no attention to productivity, motivation, efficiency or waste.

In the meantime, *Kaizen* Institute started implementing Total Flow Management. In order to guarantee the 4M's (Manpower, Machine, Material reliability and Method), a Total Productive Maintenance Project was carried out.

There was no information regarding machine Overall Equipment Efficiency (OEE), changeover time, autonomous maintenance or number of breakdowns.

The workstations did not have organization, clear work instructions, maintenance schedules nor reserved areas for manufacturing operations, WIP, and tools.

Figures 45, 46 and 47 sum up the conditions found at the beginning of the project.

Figure 47: Broaching machine in Brevini Motor Pump (part of the Brevini Fluid Power Group), September 2016.

Figure 47 allows the conditions held at the Broaching Station to be observed. Work instructions were not properly protected, nor did they have a proper space of placement, being stored between tubes of the machine.

Drawers were chaotic. Objects didn't have a place, and a place had many objects. The flow of the cell was not adapted to the cycle of work, and the work bench had obsolete tools, and was uncomfortable and not so ergonomic.

Figure 48: Vertical lathe workstation before intervention, September 2016.

Figure 48 shows another workstation, also with lack of 5s. Containers, primarily placed for holding clean and used cloths (due to the oily nature of hydraulic production), were instead being used to store obsolete tools and other items.

Bins of used oil were placed randomly in the station, valves and tubes were unattended and with functioning problems.

Figure 49: Cart used for tool change, after being filled with tools from the tool shed, September, 2016.

Figure 49 illustrates two issues: the cart of tools (the operator would travel to the tool house, submit a request for the tools needed, and then return to his workstation, wait for the arrival of the tools, and then start setting up the machine) – which implied an extra step in the process. Tools of the plant were centralized in one department, and would only be loaned upon request. This led to higher waiting times, many times with the machine already turned off. It was also common to find that the tools were not available.

The second issue visible in figure 49, is the amount of miscellaneous items stored under machines, unaddressed, unattended. Items stored under machines included: obsolete material, defects, boxes, bins of oil, vases for dripping oil, etc.

Production orders were based on an MRP system, with very big batches. One of the main reasons was the long changeover times.

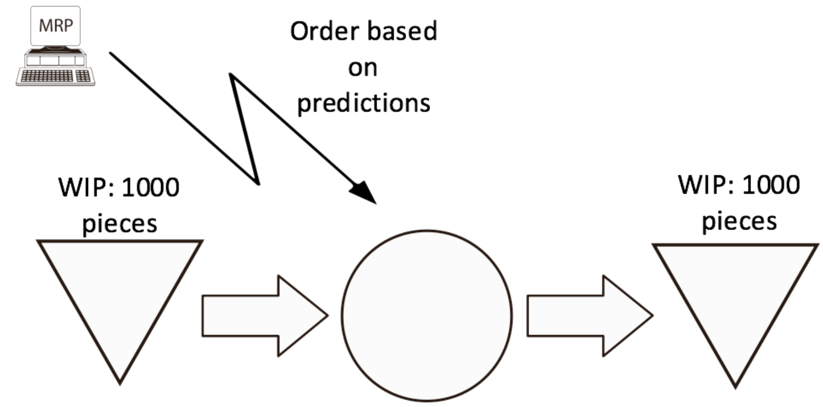


Figure 50: VSM of the normal workstation production flow at Brevini.

4.3 Proposed solution

To plan improvements, a VSD was conducted in order to identify the areas in need of intervention. From figure 51, we can read that an 80 % reduction in lot-size is needed, and that the workstation should work based on *Kanban* orders. This means, that to achieve the goal described in the VSD, SMED, 5s and Preventive Maintenance must be employed. Again, the flow must only start with a placement of a *Kanban* orders – be they withdrawal *Kanbans* or Production *Kanbans,*

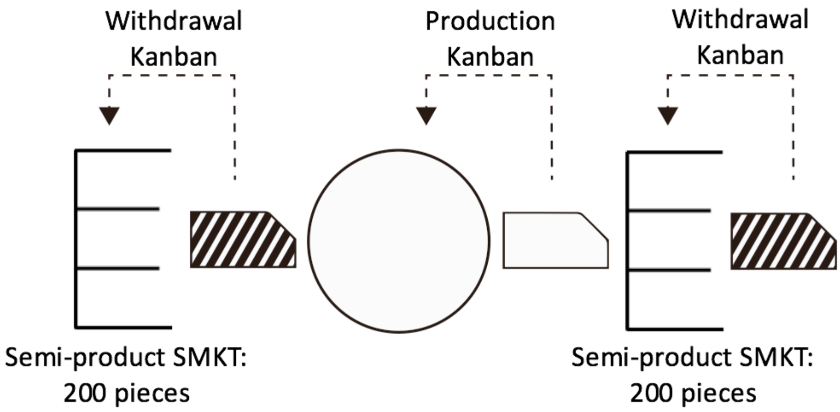


Figure 51: VSD of the ideal workstation, at Brevini.

With the scope of developing the Total Productive Maintenance project, a dynamic excel file was developed, aiming to contribute as an incentive to the shopfloor management team. This interactive dashboard, was projected to start collecting data, in a simple way, allowing the team to scientifically manage current state and evolution.

This dashboard measured the Overall Equipment Efficiency, Quality, Available Machine Time, Mean Setup time per machine, number of extraordinary maintenance interventions, and hours worked per machine, per week.

The Dashboard was designed to be simple, intuitive and the most interactive as possible. Knowing that a common server was used in the productive plant, the objective would be to save a template of the Dashboard and use one version per month, being edited in the end of each month. Because the document would be accessible to every supervisor and to the plant manager, corrective measures and analysis could be carried with data support.

With this simple method, it was expected to motivate the team to rely more on data rather than intuition and to start registering their evolution of their productive area after their continuous improvement efforts.

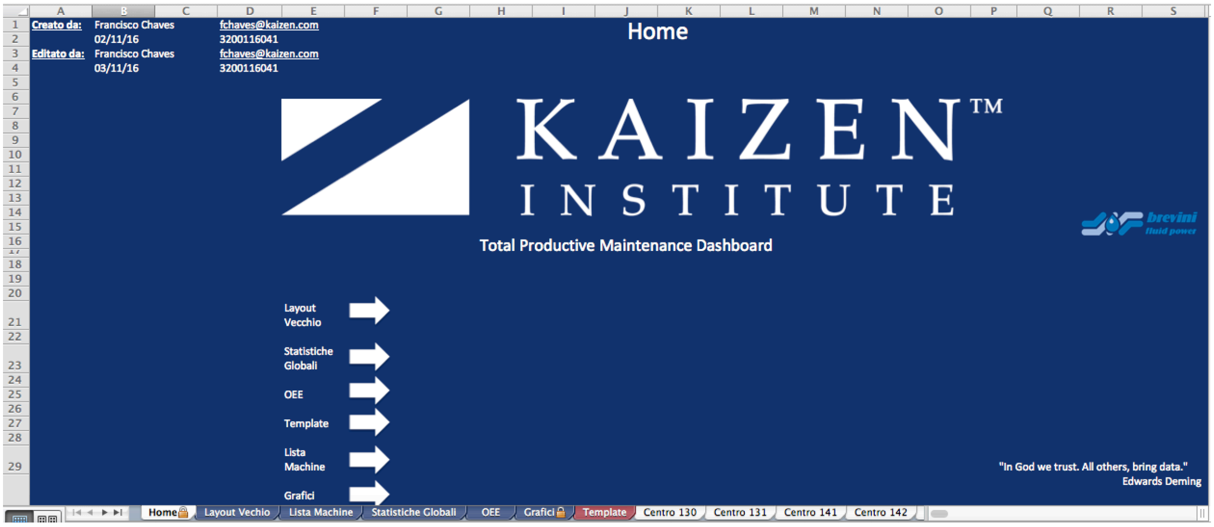


Figure 52: Screenshot of the Home menu.

On figure 52, the main menu can be observed, where the current layout can be accessed, the global statistics, OEE explanation and exercises, Templates ready to print and graphs. The main menu is highly hyperlinked in order to be the most intuitive possible.

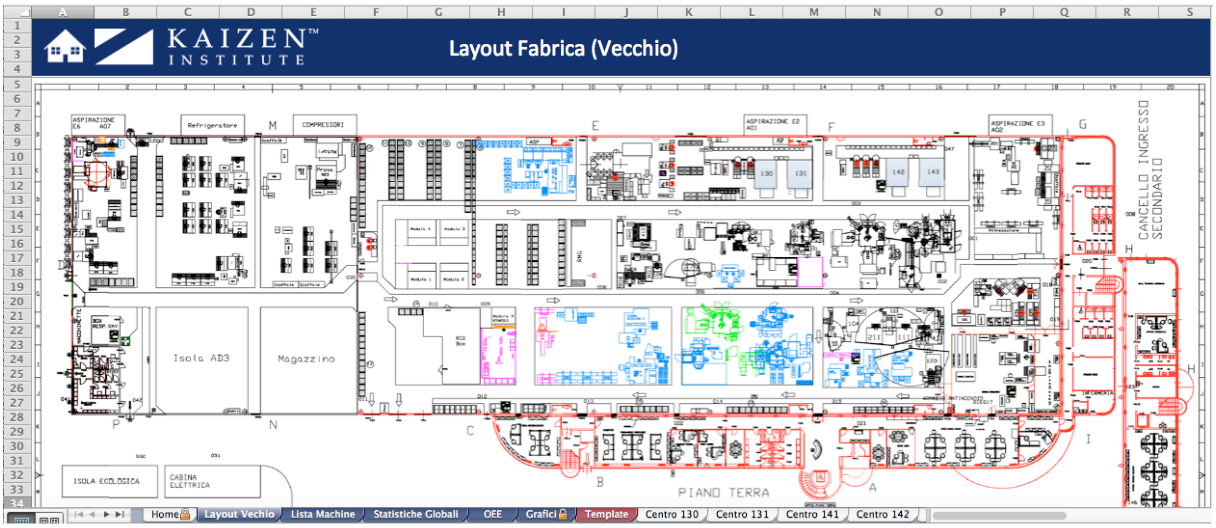
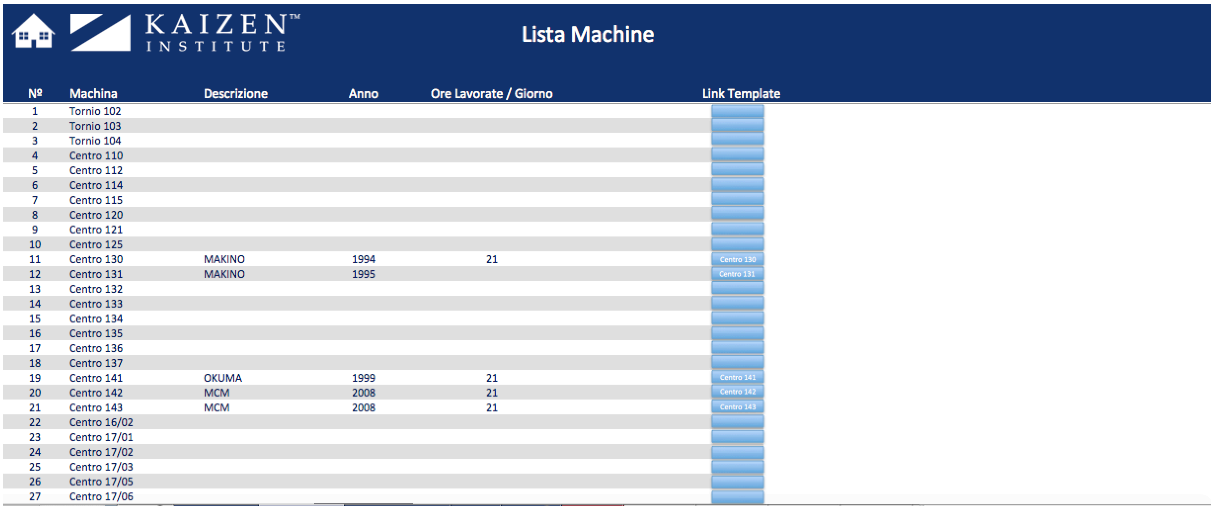


Figure 53: Screenshot of the Dynamic factory layout.

Figure 53 allows us to check the current layout, and to click on the machines – this feature allows any person that knows either the code used for the machine or the location of the machine. By clicking on, for example, the blue 131 square, we are linked to the page of the

"Centro di Lavoro 131", where the history of the machine can be recovered (breakdowns, current time of tool change, number of interventions, etc.).

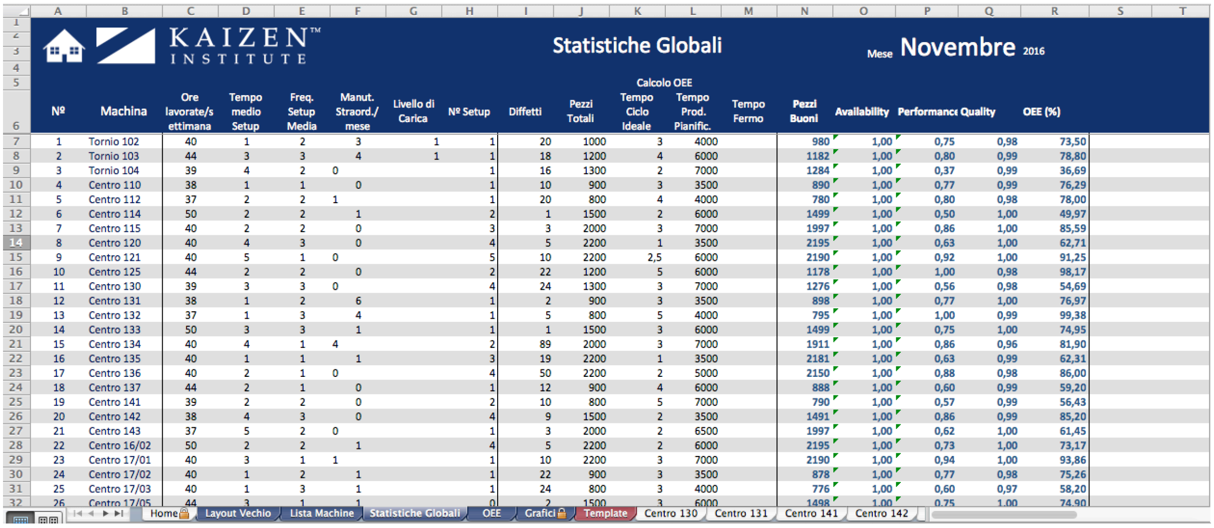


KAIZEN™ INSTITUTE — Lista Machine

Nº	Machina	Descrizione	Anno	Ore Lavorate / Giorno	Link Template
1	Tornio 102				
2	Tornio 103				
3	Tornio 104				
4	Centro 110				
5	Centro 112				
6	Centro 114				
7	Centro 115				
8	Centro 120				
9	Centro 121				
10	Centro 125				
11	Centro 130	MAKINO	1994	21	Centro 130
12	Centro 131	MAKINO	1995		Centro 131
13	Centro 132				
14	Centro 133				
15	Centro 134				
16	Centro 135				
17	Centro 136				
18	Centro 137				
19	Centro 141	OKUMA	1999	21	Centro 141
20	Centro 142	MCM	2008	21	Centro 142
21	Centro 143	MCM	2008	21	Centro 143
22	Centro 16/02				
23	Centro 17/01				
24	Centro 17/02				
25	Centro 17/03				
26	Centro 17/05				
27	Centro 17/06				

Figure 54: Screenshot of the machine and production center's section for data input, layout hyperlink and lifetime description.

Figure 54 illustrates the list of machines in this specific productive plant, containing a brief description, year in which the machine was bought, hours of work per day and a link to its template.



KAIZEN™ INSTITUTE — Statistiche Globali — Mese Novembre 2016

									Calcolo OEE								
Nº	Machina	Ore lavorate/settimana	Tempo medio Setup	Freq. Setup Media	Manut. Straord./mese	Livello di Carica	Nº Setup	Diffetti	Pezzi Totali	Tempo Ciclo Ideale	Tempo Prod. Pianific.	Tempo Fermo	Pezzi Buoni	Availability	Performanc	Quality	OEE (%)
1	Tornio 102	40	1	2	3	1	1	20	1000	3	4000		980	1,00	0,75	0,98	73,50
2	Tornio 103	44	3	3	4	1	1	18	1200	4	6000		1182	1,00	0,80	0,99	78,80
3	Tornio 104	39	4	2	0		1	16	1300	2	7000		1284	1,00	0,37	0,99	36,69
4	Centro 110	38	1	1	0		1	10	900	3	3500		890	1,00	0,77	0,99	76,29
5	Centro 112	37	2	2	1		1	20	800	4	4000		780	1,00	0,80	0,98	78,00
6	Centro 114	50	2	2	1		2	1	1500	2	6000		1499	1,00	0,50	1,00	49,97
7	Centro 115	40	2	2	0		3	3	2000	3	7000		1997	1,00	0,86	1,00	85,59
8	Centro 120	40	4	3	0		4	5	2200	1	3500		2195	1,00	0,63	1,00	62,71
9	Centro 121	40	5	1	0		5	10	2200	2,5	6000		2190	1,00	0,92	1,00	91,25
10	Centro 125	44	2	2	0		2	22	1200	5	6000		1178	1,00	1,00	0,98	98,17
11	Centro 130	39	3	3	0		4	24	1300	3	7000		1276	1,00	0,56	0,98	54,69
12	Centro 131	38	1	2	6		1	2	900	3	3500		898	1,00	0,77	1,00	76,97
13	Centro 132	37	1	3	4		1	5	800	5	4000		795	1,00	1,00	0,99	99,38
14	Centro 133	50	3	3	1		1	1	1500	3	6000		1499	1,00	0,75	1,00	74,95
15	Centro 134	40	4	1	4		2	89	2000	3	7000		1911	1,00	0,86	0,96	81,90
16	Centro 135	40	1	1	1		3	19	2200	1	3500		2181	1,00	0,63	0,99	62,31
17	Centro 136	40	2	1	0		4	50	2200	2	5000		2150	1,00	0,88	0,98	86,00
18	Centro 137	44	2	1	0		1	12	900	4	6000		888	1,00	0,60	0,99	59,20
19	Centro 141	39	2	2	0		2	10	800	5	7000		790	1,00	0,57	0,99	56,43
20	Centro 142	38	4	3	0		4	9	1500	2	3500		1491	1,00	0,86	0,99	85,20
21	Centro 143	37	5	2	0		1	3	2000	2	6500		1997	1,00	0,62	1,00	61,45
22	Centro 16/02	50	2	2	1		4	5	2200	2	6000		2195	1,00	0,73	1,00	73,17
23	Centro 17/01	40	3	1	1		1	10	2200	3	7000		2190	1,00	0,94	1,00	93,86
24	Centro 17/02	40	1	2	1		1	22	900	3	3500		878	1,00	0,77	0,98	75,26
25	Centro 17/03	40	1	3	1		1	24	800	3	4000		776	1,00	0,60	0,97	58,20
26	Centro 17/05	44	3	1	1		0	2	1500	3	6000		1498	1,00	0,75	1,00	74,90

Home | Layout Vechio | Lista Machine | Statistiche Globali | OEE | Grafici | Template | Centro 130 | Centro 131 | Centro 141 | Centro 142

Figure 55: Screenshot of the data input section.

Figure 55 illustrates the data input section, divided into global information group (on the left) and to the OEE group (on the right). This is the area where the supervisors are supposed to insert data, in order to measure and act on their sectors.

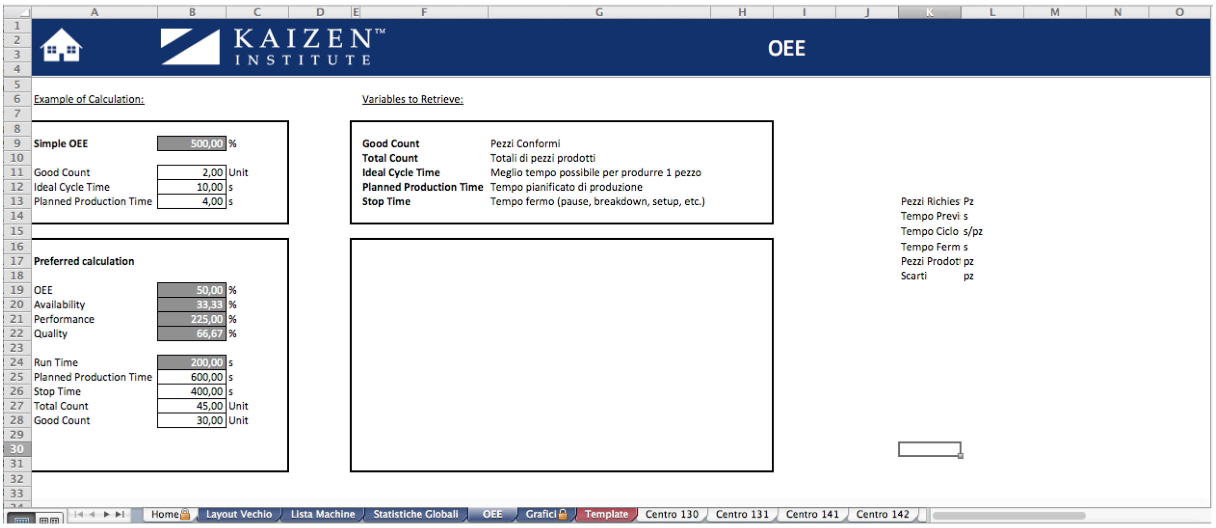


Figure 56: Screenshot of the OEE explanation and example exercises.

Figure 56 shows the OEE Simulation Section, where anybody who isn't entirely at ease with the concept of OEE can test the algebraic formula, revise basic concepts and learn how to use and manipulate the OEE. This feature is expected to lighten the load of using an external tool and to educate the user on which variables are useful to improve his Gemba in order to achieve the desired OEE.

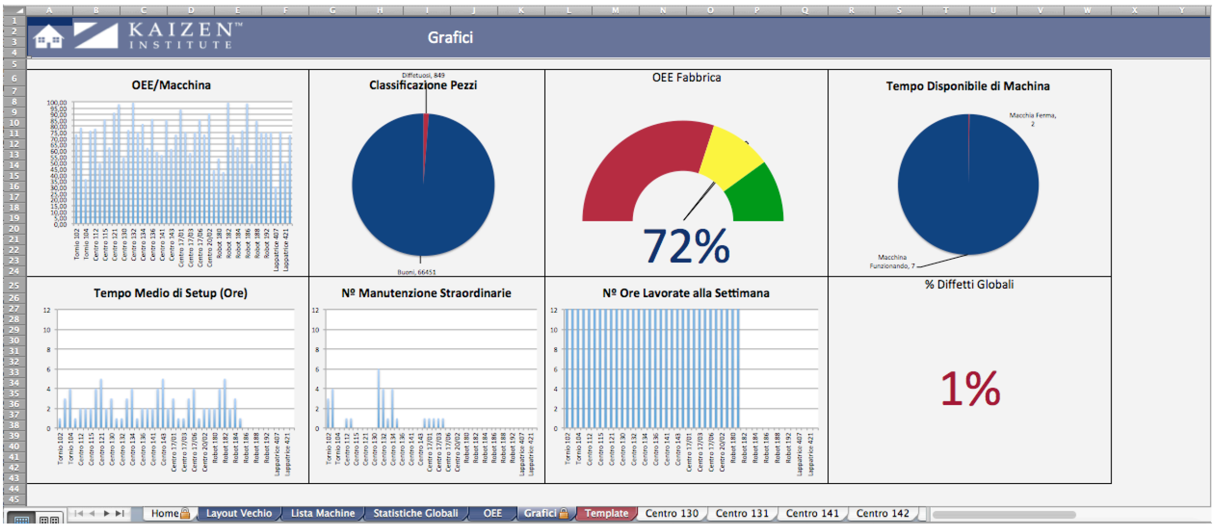


Figure 57: Screenshot of the graph section, with main KPI's.

The dashboard represented on figure 57 allows management and the supervisor's team to swiftly analyze the main KPI's of the machines in the plant, allowing quick response in intervention, improvement planning and quality and control intervention. A big effort was done on creating a simple dashboard, with clear, visual statistics, in order to reduce complexity and to communicate in a fast, effective way.

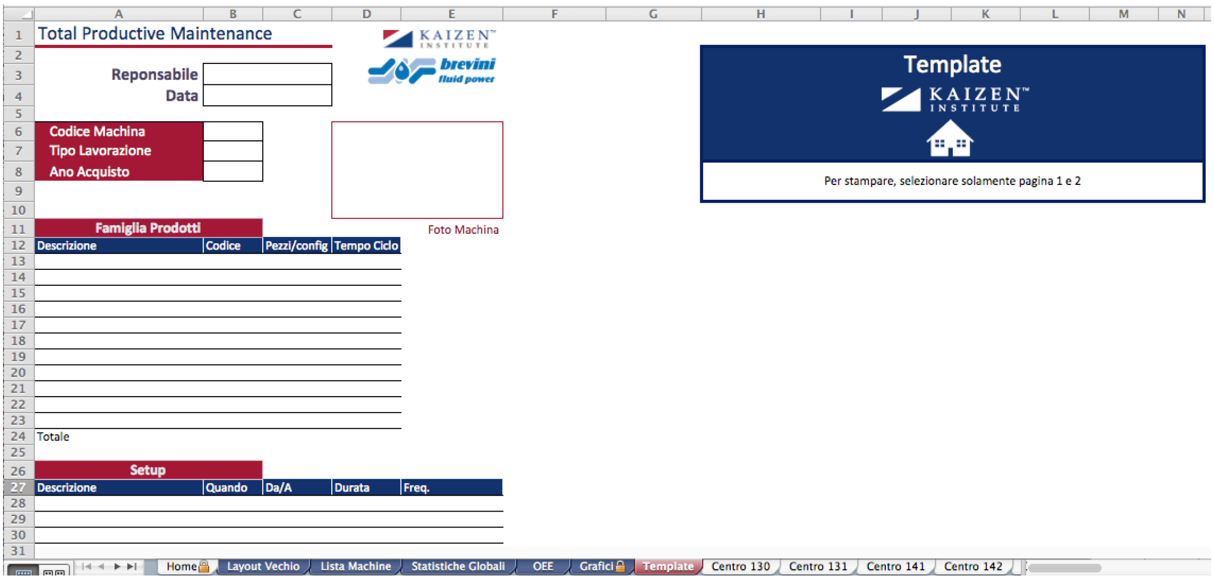


Figure58: Screenshot of the templates, ready to print for data collection in the Gemba.

Due to the lack of conditions for the use of computers inside the productive area, a section with a printable template was created (figure 58). Instructions were created for easy printing, allowing a correct data collection, and posterior data insertion in the dashboard. This way, the problem of not having the Dashboard on the Gemba was solved, still allowing it to be used.

To deploy TPM in each machine or work station, it was decided to create a script: application of SMED, followed by implementation of 5s, followed by development of Autonomous Maintenance and Professional Programmed Maintenance.

The sequence SMED, 5s, Autonomous Maintenance was key for the success of actions, acting as an enabler in the team management and reducing resistance.

In order to preform SMED correctly, the workplace will need proper organization, which will urge the team to indulge in a 5s program.

Sorting up a workstation will reveal several problems that can later be addressed with the maintenance intervention, which, had the area not been intervened, would leave several points out. Figure 59 shows the Gantt Chart relative to the project.

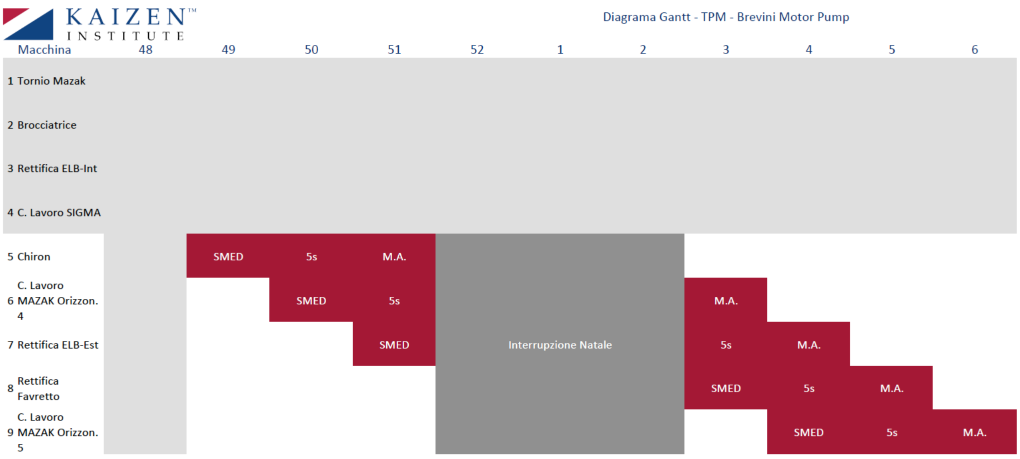


Figure 59: Gantt chart produced for the TPM intervention at Brevini Motor Pump.

SMED was carried out on a Chiron multicenter, passing from an 89 minute tool change to a 12 minute change. On figure 60, a screenshot of a video footage can be observed. The reason why the operation was recorded was to enable a careful analysis, not only to understand the process, but also to spot inefficiencies of the process. The video was watched with the TPM team, composed by a team leader, shift supervisor, and continuous improvement team members.

Figure 60: Screenshot of a video footage of a tool change on a Chiron workstation at Brevini Motor Pump (Part of Brevini Fluid Power), November 2016.

During the tool change, a spaghetti chart and a list of the tasks preformed, with description of duration, were drawn and taken. These elements, together with the footage, allowed the team to analyze the source of inefficiencies, and carry out the process of SMED.

Figure 61 represents the result of a SMED workshop.

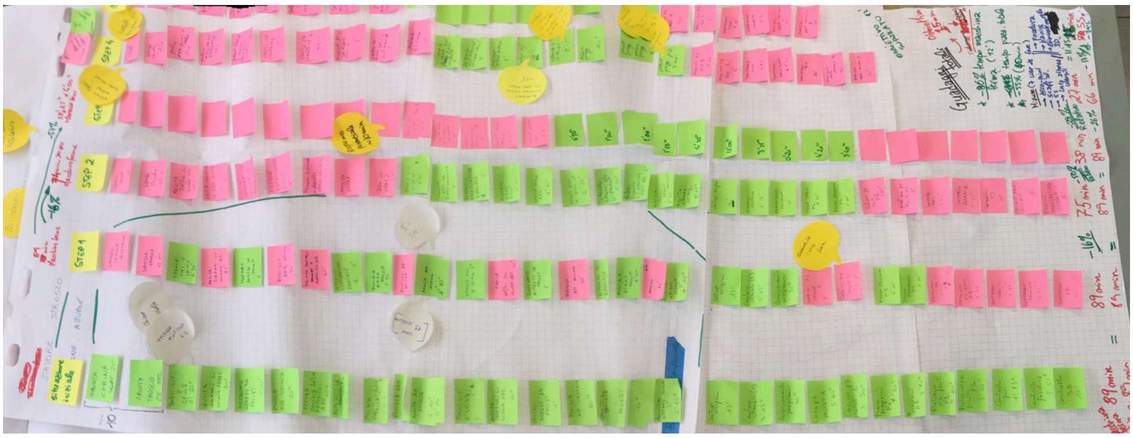


Figure 61: SMED process for a Chiron bi-pallet (From 89 to 12 minutes). Result of a workshop done at Brevini Motor Pump, December 2016.

In order to convince the team to follow the process from beginning to end, it was decided to keep the "post-its" from all five steps. Figure 57 should be read from bottom to top, left to right. The first row represents "step 0", or the initial situation – where all steps are undefined and undistinguished. "Step 1" illustrates the first effort, classifying operations into either "External", represented in pink, or "Internal", represented in green. External operations refer to all tasks that can be performed without the need to shutdown the machine, or interrupt production. Internal operations refer to all the tasks where the machine must be shut down, in order to be carried out.

"Step 2" shows a redefinition in the order of the operations. From this step, external operations are performed either before the machine is shutdown, or after the machine is turned on again.

"Step 3" shows the conversion of internal operations into external operations. Let it be noted that there has already been a saving on the time the machine is unavailable. Total operations still remain the same, but now allow the machine to be spent down less time.

"Step 4" shows the reduction of internal work. A fast bolting system was implemented, consequently saving external work as well, called "Zero-Point". This feature had an approximate cost of 4 500€. The payback period was estimated to occur around the 24th setup, which, with normal production, should occur around 90 days.

This investment, however, is considered maintaining the current number of setups. Naturally, as the setup time decreases, smaller batches are produced, and more frequently setups are done. This leads to a shorter payback period than estimated, bringing also reductions in warehouse costs. The opportunity cost, which has been severely reduced, as well, is not considered.

"Step 5", where reduction of external work was performed, was achieved through the organization of the workplace, by redesigning the line and tool displacement.

Figure 62 shows the savings achieved between each step, in terms of turned off machine, and total operating time.

	Step 0	**Step 1**	**Step 2**	**Step 3**	**Step 4**	**Step 5**
Time with Machine OFF (minutes)	89	89	75	38	27	12
Total time of Operations (minutes)	89	89	89	89	66	55
Relative OFF Time reduction	N.A.	0%	-16%	-49%	-29%	-56%
Absolute OFF Time reduction	N.A.	0%	0%	-57%	-70%	-87%
Relative Total Operation Time Reduction	N.A.	0%	0%	0%	-26%	-17%
Absolute Total Operation Time reduction	N.A.	0%	0%	0%	-26%	-38%

Figure 62: Relative and Absolute time reductions and savings, in shutdown time and total operating time.

To support the changes done, a tool trolley was prototyped, in order to reduce traveled distance during the Setup. This trolley can be observed on figure 63.

Figure 63: Proposed tool trolley, and tool layout, for Exchange of tools.

After the SMED workshop, a 5s action was usually deployed. In figure 64, a game used to introduce the theme is visible. The figure is composed by six Figures (one page each). The first Figure, only squares, represents a cabinet with shelves, while the remaining represent tools. Figures 2 through 6 are given, in order, measuring the performance of cutting, setting in order, and placing each letter on each shelf, in the proper alphabetical order. Naturally, as the game progresses, the complexity diminishes, as 5s is applied to each scheme (removing numbers, grouping letters, standardizing fonts, using visual management, etc). This exercise creates a sensation of need to change, creating thus, conditions to sustain a 5s action.

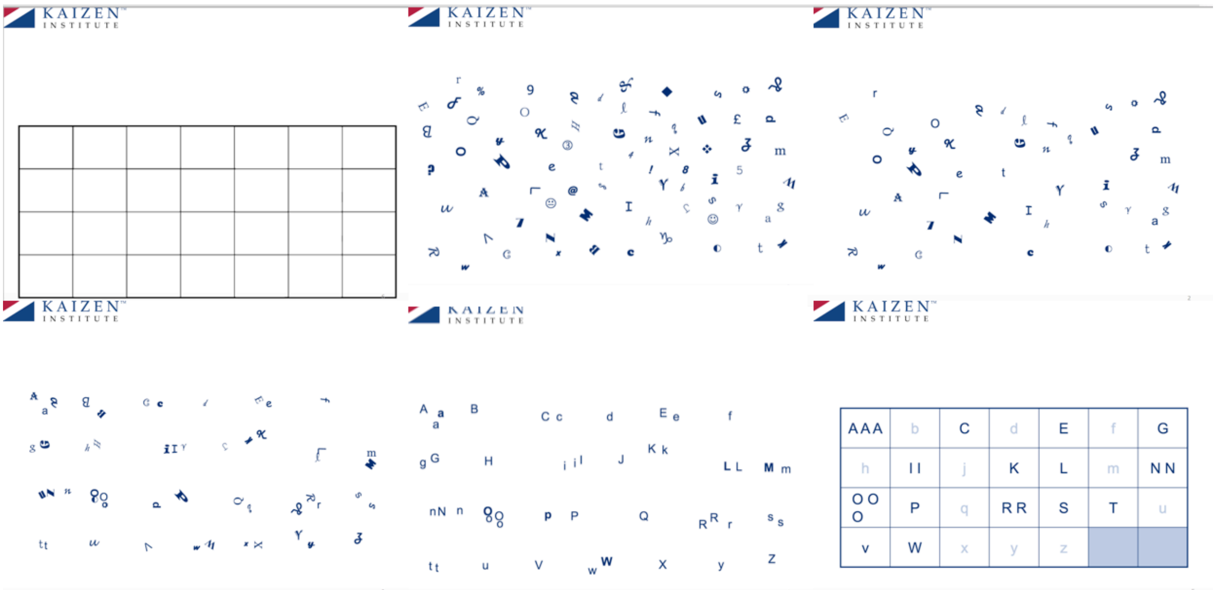


Figure 64: 5s game.

Figures 65 through 67, show the results obtained after the first 5s iteration. Most of the items removed were either sent to the warehouse, for posterior decision.

Figure 65: Broaching station after 5s, November 2016 (Brevini Motor Pump).

One of the main objectives during the 5s action was to reduce the number of tools available in the workstations. There were too many, and most of them without justification. It was, however, noticed, that the operators were very reluctant to give up their tools, with the fear that in the future they would come up short. A way to avoid resistance was to create a temporary tool shed, or a quarantine. This allowed the operators to be relieved, knowing where to find these items in case of need. On the other hand, if they weren't used in the following 20 days, they would disappear.

Figure 66: Milling station after 5s, November 2016 (Brevini Motor Pump).

One of the main improvements, during 5s, was the creation of instruction holders, in visible, accessible places.

Due to the type of industry, lots of cloths are normally used. Bins for used and clean cloths were created, along with instructions of deposit and withdrawal of clean and dirty cloths.

Figure 67: Tool shelf, labeled and organized, next to machine's setup area.

Labeling tools was also essential for operations. By labelling them, during tool change, decision times were shorter, and less mistakes were done. By having the references, the operators were quicker attributing de CNC code to each tool, and more confident.

Once the work stations were clear, problems were more visible than ever. Puddles of oil, rust, non-sealed valves, etc.

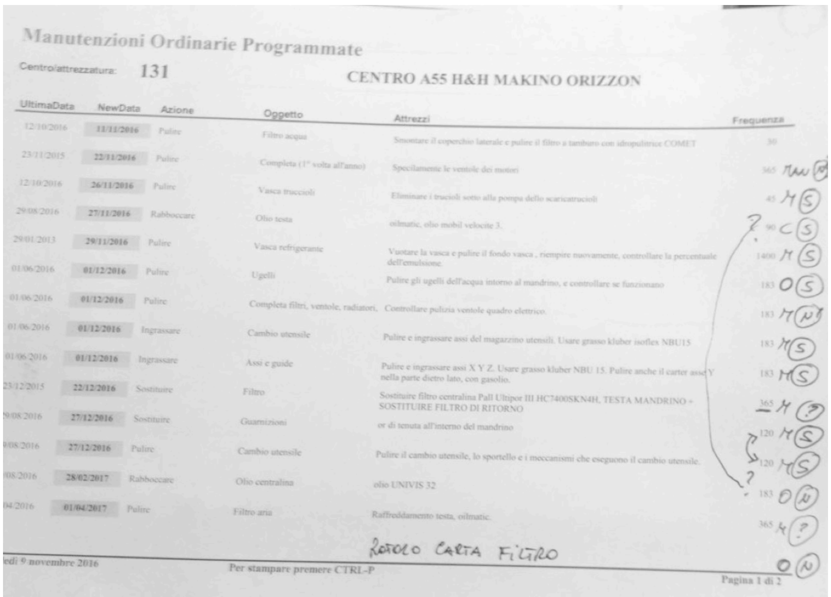
A problem noticed, was the refusal to take responsibility for the troubles found. Operators, Shift Leaders and Engineers were not willing to accept these troubles as part of their duties. When discussing the root causes, they would constantly argue. For this reason, the "Cartellini Rossi", or "Trouble Tickets" were employed (figure 68 illustrates their use).

Figure 68: Use of colored trouble tickets to signal malfunctions, dangerous situations or functions that require preventive/frequent/regular maintenance or substitution, implemented in Brevini Motor Pump, December 2016.

Trouble tickets were placed in every single spot that had a malfunction, or that needed periodical substitution (like filters, filter-paper, oil, water, etc.), and later, photos of all the cards were taken. After these elements were collected, they were discussed in a workshop. By having a photo of the problem, its description, no blaming or refusal to acknowledge problems was done. This process allowed to discharge all the emotional attachment and simply solve root causes in the machine's malfunctioning or breakdowns.

The existing professional maintenance schedule was also analyzed (figure 69). It was insufficient, and interventions were very far apart from each other, being set 6 months apart or more.

All the points in the existing schedule were discussed, being questioned if the tasks really needed professional intervention, if they really were being done in a reasonable frequency, and if it really was enough.



Manutenzioni Ordinarie Programmate

Centro/attrezzatura: 131 CENTRO A55 H&H MAKINO ORIZZON

UltimaData	NewData	Azione	Oggetto	Attrezzi	Frequenza
12/10/2016	11/11/2016	Pulire	Filtro acqua	Smontare il coperchio laterale e pulire il filtro a tamburo con idropulitrice COMET	30
23/11/2015	22/11/2016	Pulire	Completa (1° volta all'anno)	Specilamente le ventole dei motori	365 MAN R
12/10/2016	26/11/2016	Pulire	Vasca truccioli	Eliminare i trucioli sotto alla pompa dello scaricatrucioli	45 M S
29/08/2016	27/11/2016	Rabboccare	Olio testa	oilmatic, olio mobil velocite 3.	? 90 C S
29/01/2013	29/11/2016	Pulire	Vasca refrigerante	Vuotare la vasca e pulire il fondo vasca , riempire nuovamente, controllare la percentuale dell'emulsione.	1400 M S
01/06/2016	01/12/2016	Pulire	Ugelli	Pulire gli ugelli dell'acqua intorno al mandrino, e controllare se funzionano	183 O S
01/06/2016	01/12/2016	Pulire	Completa filtri, ventole, radiatori.	Controllare pulizia ventole quadro elettrico.	183 M N
01/06/2016	01/12/2016	Ingrassare	Cambio utensile	Pulire e ingrassare assi del magazzino utensili. Usare grasso kluber isoflex NBU15	183 M S
01/06/2016	01/12/2016	Ingrassare	Assi e guide	Pulire e ingrassare assi X Y Z. Usare grasso kluber NBU 15. Pulire anche il carter asse Y nella parte dietro lato, con gasolio.	183 M S
23/12/2015	22/12/2016	Sostituire	Filtro	Sostituire filtro centralina Pall Ultipor III HC7400SKN4H, TESTA MANDRINO + SOSTITUIRE FILTRO DI RITORNO	365 M ?
29/08/2016	27/12/2016	Sostituire	Guarnizioni	or di tenuta all'interno del mandrino	120 M S
29/08/2016	27/12/2016	Pulire	Cambio utensile	Pulire il cambio utensile, lo sportello e i meccanismi che eseguono il cambio utensile.	120 M S
08/2016	28/02/2017	Rabboccare	Olio centralina	olio UNIVIS 32	? 183 O N
04/2016	01/04/2017	Pulire	Filtro aria	Raffreddamento testa, oilmatic.	365 M ?
				ROTOLO CARTA FILTRO	O N

edi 9 novembre 2016 Per stampare premere CTRL-P Pagina 1 di 2

Figure 69: Existing professional maintenance schedule from Brevini Motor Pump, November 2016.

Having checked and redefined the professional maintenance, collected the recurrent problems found in the trouble tickets, a checklist for autonomous maintenance was developed.

Most of the tasks defined were simple, sometimes being, for example, just checking the level of oil. The effort and time needed were taken into account, and tasks were set according to the periodical need, having been color-coded. Yellow for once a day, Blue for once a week and Green for once a month. An example of an autonomous maintenance checklist created can be observed on figure 70.

Responsibilities were also attributed, to either operator, shift leader or maintenance crew. Security accessories were also included, such as protective goggles and gloves.

After this schedule was produced, it was presented to operators, who often suggested improvements on the schedule, further developing it. A sheet to document the date of maintenance performed and duration of each task, and a reserved space for the supervisor to confirm.

A layout of the workstation was also provided (figure 71), in order to simplify explanation of the intervention, and to clearly indicate the spots to watch out for. Each number on the layout refers to the number of each task in the maintenance checklist.

These documents were all plasticized and made portable, in order to allow the operator to carry it while preforming his duties, reducing traveled time and distance.

All the actions were also taught to the operators, being performed in front of them, then with them, and then supervising them. This training step was crucial to the accomplishment of the schedules and maintenance of the new standard – as, in the beginning, operators were scared of the new responsibilities.

brevini fluid power – Division of Brevini Group		REPARTO LAVORAZIONI MECCANICHE ISTRUZIONI ATTIVITA' DI TPM - MAN. AUTONOMA CDL 130			R00 DEL 10/11/2016 STAB. FLUID	CDL 130
RIF. LAYOUT	**RIF. FOTOGRAFICO**	**DESCRIZIONE**	**AZIONE CORRETTIVA**	**Cadenza (gg)**	**OPERATORI COINVOLTI**	**DPI DA USARE**
1		Ugelli mandrino	Pulire ugelli del mandrino e controllare se funzionano	1 VOLTA AL MESE		
2		Livello olio cambio utensile posizionato dentro la macchina	Controllo visivo: al di sotto del livello minimo procedere al rabbocco.	1 VOLTA AL MESE		
3		Filtro acqua	Smontare coperchio laterale e pulire filtro a tamburo con idropulitrice	1 VOLTA AL MESE		
4		Carta filtro vasca refrigerante	Verificare che la carta residua sia sufficiente alla lavorazione non presidiata e all'occorrenza sostituire	1 VOLTA AL GIORNO		
5		Controllo livello serbatoio centralina	Controllo visivo: al di sotto del livello minimo procedere al rabbocco. (UNIVIS 32)	1 VOLTA AL MESE		
6		Verifica stato filtro Pall Ultipor 3	Controllo visivo se segnale è rosso avvisare manutenzione	1 VOLTA AL GIORNO		
7		Controllo livello serbatoio centralina olio testa	Controllo visivo: al di sotto del livello minimo procedere al rabbocco. (Mobil Velocite 3)	1 VOLTA A SETTIMANA		
8		Pulizia filtro aria raffreddamento testa	Lavare in lavatrice e dopo asciugare	1 VOLTA AL MESE		

Figure 70: Checklist of autonomous maintenance to be done, with corresponding frequencies, responsibilities and locations, implemented in Brevini Fluid Control, created after TPM workshop (Part of Brevini Fluid Power).

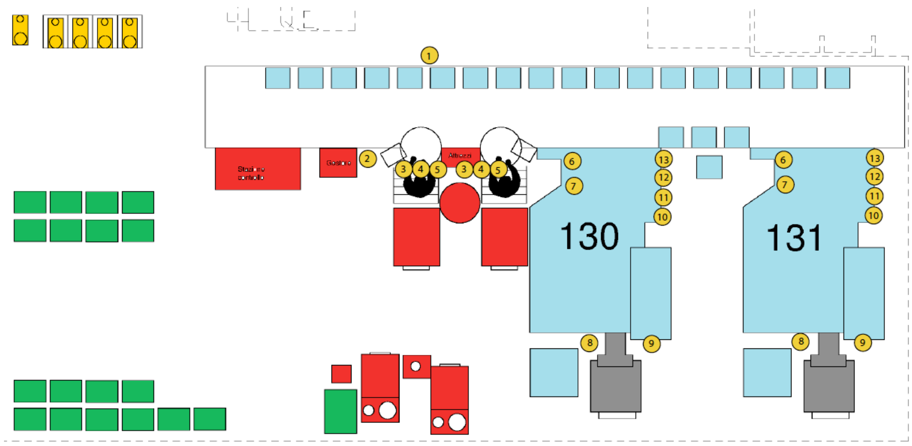


Figure 71: Layout of workstation with critical autonomous maintenance points signaled, implemented in Brevini Fluid Control (Part of Brevini Fluid Power).

Figure 72 shows one of the PDCA boards used during the project. A big effort to make it visually appealing and keep it updated. It was frequent to see operators, not yet involved in the project, approaching the board, reading the actions undertaken, checking the results and the new standards. Some of these operators did in fact question their supervisors about not having yet been involved in the *Kaizen* activities, and when would their chance to improve come. This definitely reduced resistance as the project progressed, and actually motivated the team.

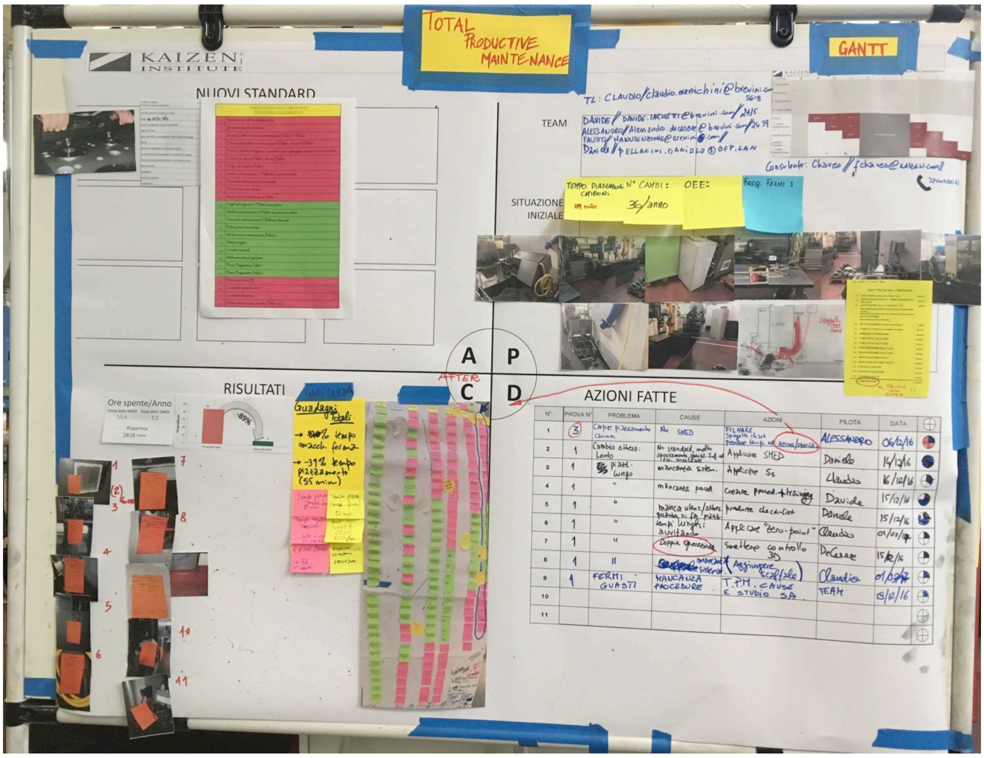


Figure 72: PDCA Board used to manage the TPM project.

4.4 Commentaries

Collection of data was a big challenge during the implementation, even after a tailored platform was projected and delivered.

High reluctance in trusting data collected by operators was felt, being noticed that information was concentrated in the "Programming department", which also was found to be measuring incorrectly several KPI's, including, for example, Personnel Productivity in the OEE statistics. This is one of the main reasons for the absence of statistical comparison of the "Before" and "After" in this chapter.

Brevini had not yet achieved data and information sharing as common practice, nor had yet felt it to be crucial to the group's growth and development, especially with the shop floor workers.

One of the main difficulties in the implementation of TPM was also a reluctance to follow methodic processes, especially in the fields of SMED and Autonomous Maintenance, meaning that the team had a hard time controlling the urge to "Jump into a quick solution".

There was a high reluctance to involve operators, due to the lack of trust on expertise and experience.

A key factor to be consider is the local labor union, who forbade the video-recording of operators, having stood an impediment to the recording of tool-changes, fundamental for a correct, methodical following of the SMED Method. This obstacle was overpassed using an action camera in the operator's helmet, guaranteeing no operator would show up in the footage.

Brevini Fluid Power was also involved in a big acquisition, in the order of 80%, by the American group Dana Incorporated, valuing Brevini Group at 325 M€. This merge destabilized the TPM team in the final period of the intervention, due to the requirement of the team members for other issues concerning the company's transformation.

4.5 Implementation results

After the implementation of Total Productive Maintenance in Brevini Fluid Power, considerable improvements were met.

Setup times were reduced to some astonishing 87% and zero breakdowns have succeeded since.

After the SMED intervention a total annual saving of 22 464 € was achieved. The total savings can be seen on figure 73.

Result of SMED at Brevini	
Cost of Setup (€/h)	90
Setup Time Before (h)	1,5
Setup Time After (h)	0,2
Time Saved (h)	1,3
Money Saved Per Setup (€)	117
Number of Setups / Year	192
Yearly Savings (€)	22464

Figure 73: Total savings achieved at Brevini after SMED.

These results, however, took more than expected to be met. The team still had a serious difficulty in following method and process, and jumped into obvious solutions, most of the times incurring into unnecessary investments.

The 5s action, although bringing big improvements, was still insufficient, being one of the main reasons the non-involvement of operators, who later fail to support the changes made, and complained about the new layouts.

In order to continue improving, Brevini must definitely start delegating more responsibilities to their shop-floor workers, and invest on personnel training.

Brevini must also stop regarding 5s as a punctual activity, done once or twice a year, and understand that good house-keeping is a continuous, never-ending process, involving everyone in the company, from shop-floor worker to the CEO.

Chapter 5: Scenario C – Reduction of 25% value in stock in a furniture productive supply chain

5.1 Introduction

Alf produces a big range of furniture, mainly for the bedroom and for the living room. Their products, mainly produced in wood, contain, as well, metallic accessories, acquired from Italian and international suppliers, representing an approximate total of 100 suppliers.

These accessories, fundamental for the function of furniture (rails, hinges, bolts, etc.) are not standardized in the company's conception department, representing a high variability in stock.

These components also represent a high investment from the company, which can't be used for investment on R&D or market research.

This non-performing capital impedes the company's growth and must urgently be minimized – therefore, the defined challenge for the intervention was "Reduction of 25% of stock in the warehouse, from 800 000€ to 600 000€".

5.2 Presentation of the problem

Alf had a problem managing components inventory management, mostly due to the absence of control and synchronization inside the group.

The team wasn't sure about their levels of inventory, rate of consumption, or even the significance they represented to their suppliers, to their customers and vice-versa in terms of net worth.

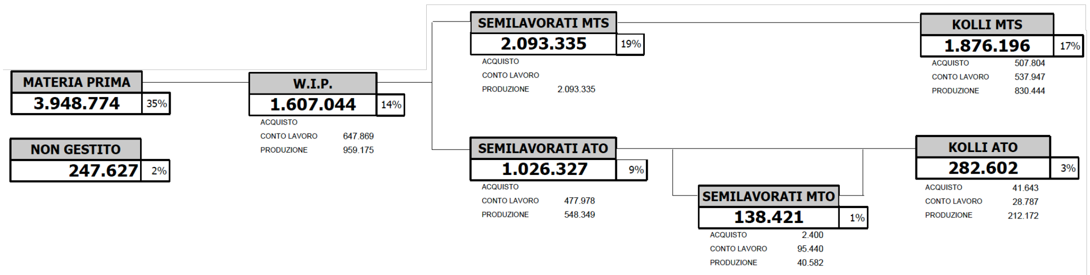
There was no concern given to the seasonality of the demand, and stock was uncontrolled.

The acquisition of supplies was done on a forecasting method, in two independent stocking establishments, with unpredictable deliveries. The only analysis was done on the annual report, visible on figure 74.

The root causes were linked to irregular relationships with suppliers and absence of information sharing and control between the two warehouses.

Buying orders were controlled through an MRP System, with closed orders, meaning that Alf would buy large quantities without previous warning, destabilizing the suppliers production program, creating large variations in production and contributing for a big bullwhip effect.

Alf operated without any agreement with suppliers, which implicated business insecurity, with no predictions on income and production, large fluctuations of demand and high peaks of service. Alf also demanded their suppliers to deliver in many points, further amplifying the bullwhip effect.



		NEWS	ATTIVO	OUT	BASSA ROT.	Totale	%BrOut	F12m	I.R.	Mag IR5 (OBIETTIVO)	IR-IR5 (OBIETTIVO)	Portafoglio
STILE MODERNO	34%	1.385.990	2.269.269	93.198	22.438	**3.770.895**	2 %	21.209.550	**5,4**	4.065.164	8%	3.310.505
STILE CLASSICO	4%		466	4.672	450.295	**455.433**	1 %	703.142	**1,5**	134.769	-70%	131.269
STILE ETNICO	61%	1.910.965	4.019.735	254.857	674.992	**6.860.548**	4 %	48.738.924	**6,8**	9.341.627	36%	9.166.566
NEUTRO	1%		133.450			**133.450**		8.429		1.616	-99%	503
Totale		**3.296.954**	**6.422.919**	**352.727**	**1.147.725**	**11.220.326**	3 %	70.660.045	**6,0**	13.543.175	21 %	12.608.844
		29 %	57 %	3 %	10 %							

		1	%	2	%	3	%	4	%	5	%
	MATERIA PRIMA	3.839.207	6,3%	3.878.737	7,4%	3.738.555	3,5%	3.634.693	0,7%	3.743.009	3,7%
MATERIA PRIMA		3.839.207	6,3 %	3.878.737	7,4 %	3.738.555	3,5 %	3.634.693	0,7 %	3.743.009	3,7 %
	SEMILAVORATI MTO	135.081	-5,5%	125.869	-11,9%	112.961	-21,0%	132.652	-7,2%	257.425	80,1%
	SEMILAVORATI PER ATO	1.164.467	3,4%	1.211.883	7,6%	1.266.587	12,5%	1.314.052	16,7%	1.302.607	15,7%
	SEMILAVORATI PER MTS	1.321.187	-8,9%	1.459.180	0,6%	1.573.504	8,5%	1.632.935	12,6%	1.788.593	23,3%
	SEMILAVORATI WIP	1.816.633	16,2%	1.794.497	14,8%	1.766.261	13,0%	1.456.726	-6,8%	1.383.368	-11,5%
SEMILAVORATI		4.437.368	3,6 %	4.591.429	7,2 %	4.719.314	10,2 %	4.536.365	5,9 %	4.731.993	10,5 %
	COLLO ATO	258.174	6,4%	273.337	12,6%	290.898	19,8%	209.138	-13,8%	215.929	-11,0%
	COLLO MTS	1.830.361	50,5%	2.379.374	95,6%	2.528.866	107,9%	2.428.750	99,7%	2.279.718	87,4%
COLLI		2.088.535	43,1 %	2.652.711	81,8 %	2.819.764	93,3 %	2.637.888	80,8 %	2.495.646	71,0 %
	NON GESTITO	262.836	6,6%	260.242	5,6%	279.897	13,5%	259.337	5,2%	309.291	25,5%
	PRECONFIGURATO	12.495	-44,8%	15.454	-31,7%	31.000	37,1%	33.030	46,0%	105.429	366,2%
VARIE		275.331	2,3 %	275.696	2,4 %	310.896	15,5 %	292.366	8,6 %	414.720	54,1 %
	Totale Mensile	**10.640.441**	10,6 %	**11.398.573**	18,5 %	**11.588.529**	20,4 %	**11.101.313**	15,4 %	**11.385.368**	18,3 %

		6	%	7	%	8	%	9	%	10	%
	MATERIA PRIMA	3.832.488	6,1%	3.728.419	3,3%	3.750.941	3,9%	3.989.202	10,5%	3.948.774	9,4%
MATERIA PRIMA		3.832.488	6,1 %	3.728.419	3,3 %	3.750.941	3,9 %	3.989.202	10,5 %	3.948.774	9,4 %
	SEMILAVORATI MTO	134.463	-5,9%	156.367	9,4%	142.824	-0,1%	135.264	-5,4%	138.421	-3,2%
	SEMILAVORATI PER ATO	1.253.348	11,3%	1.078.108	-4,2%	1.025.729	-8,9%	996.665	-11,5%	1.026.327	-8,8%
	SEMILAVORATI PER MTS	1.724.158	18,8%	1.836.009	26,6%	1.718.714	18,5%	1.908.441	31,5%	2.093.335	44,3%
	SEMILAVORATI WIP	1.409.651	-9,8%	1.418.875	-9,2%	1.344.913	-14,0%	1.610.207	3,0%	1.607.044	2,8%
SEMILAVORATI		4.521.620	5,6 %	4.489.359	4,8 %	4.232.180	-1,2 %	4.650.577	8,6 %	4.865.127	13,6 %
	COLLO ATO	265.723	9,5%	291.526	20,1%	293.416	20,9%	295.853	21,9%	282.602	16,4%
	COLLO MTS	2.415.244	98,6%	2.378.008	95,5%	1.578.815	29,8%	2.175.133	78,8%	1.876.196	54,3%
COLLI		2.680.967	83,7 %	2.669.535	83,0 %	1.872.231	28,3 %	2.470.986	69,4 %	2.158.798	48,0 %
	NON GESTITO	277.632	12,6%	299.152	21,4%	310.248	25,9%	276.623	12,2%	196.510	-20,3%
	PRECONFIGURATO	55.513	145,5%	62.106	174,6%	54.497	141,0%	54.312	140,1%	51.117	126,0%
VARIE		333.145	23,8 %	361.258	34,2 %	364.744	35,5 %	330.935	23,0 %	247.627	-8,0 %
	Totale Mensile	**11.368.220**	18,1 %	**11.248.570**	16,9 %	**10.220.097**	6,2 %	**11.441.699**	18,9 %	**11.220.326**	16,6 %

Figure 74: Value of merchandise in warehouse.

Figure 70 allows us to analyze the weight of each product in terms of quantity and warehouse cost, clearly indicating the suppliers that represent the main expenses. This information allows us to understand where to intervene, in order to reduce effectively the value of stock.

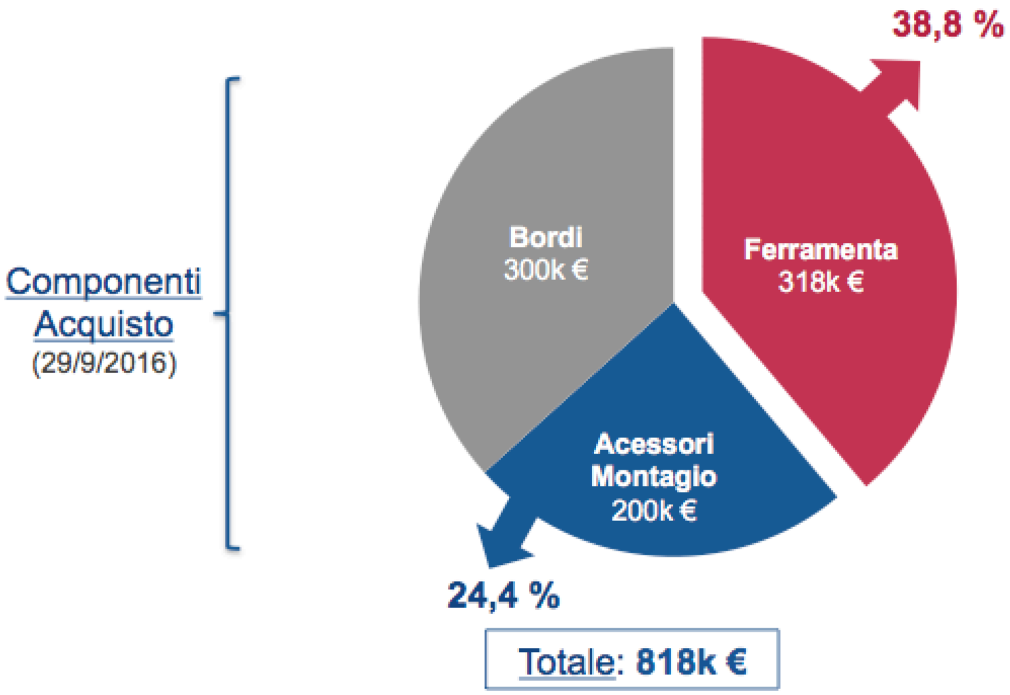
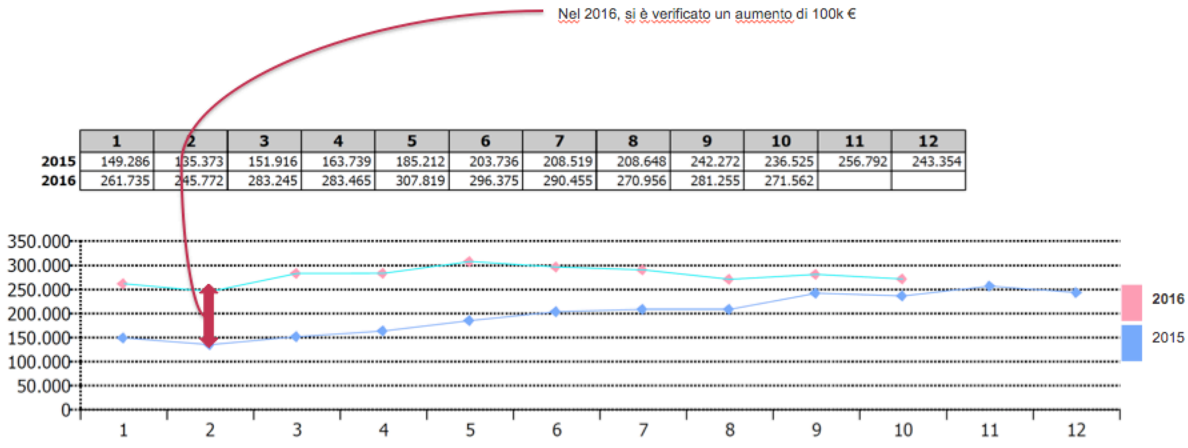


Figure 75: Percentage of stock in warehouse [Assembly accessories (blue), Tools (red), Edgings (grey)].

An analysis on the type of merchandise was carried, in order to group the type of components. Items were classified into Assembly Accessories of the furniture, Edgings and Tools (figure 75). We can easily understand that intervening in the tooling materials would affect the most the inventory, thus helping us approach the solution.



	1	2	3	4	5	6	7	8	9	10	11	12
2015	149.286	135.373	151.916	163.739	185.212	203.736	208.519	208.648	242.272	236.525	256.792	243.354
2016	261.735	245.772	283.245	283.465	307.819	296.375	290.455	270.956	281.255	271.562		

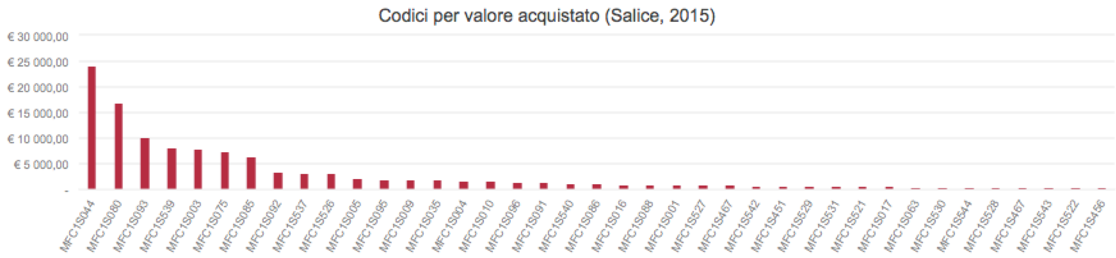
Figure 76: Increment of tool supplier's in-house value between 2015 and 2016.

The next step to understand the problem was to study the fluctuations of inventory in the recent past (figure 76), analyzing the fluctuation on acquisition. It was understood that 2016 had been a year of heavy spending, mostly due to an increase on demand. The total increase on investment was roughly 100 000€.

Figure 77: Frequency of orders to supplier in 2016, against quantity.

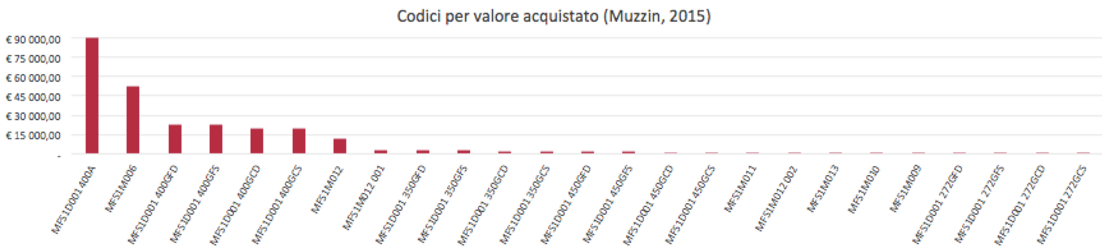
The buying habits of a specific supplier, which can be observed on figure 77, also shows the type of behavior carried with suppliers, with high volumes in punctual cases, representing an overload to the supplier, justifying the high values of stock. This behavior causes high amounts of warehouse load, due to the use of annual replenishments.

It was decided to study the two most representative suppliers, taking into account all their SKU’s and quantities. For the effect, Salice, one of the main suppliers of hinges and Muzzin, a big supplier of drawer rails, were taken into account. The corresponding range of supplied products can be observed on figures 78 and 79, respectively.



CODICE	DESCRIZIONE	ACQ. 2015	VALORE	C.U.	GIAC.	GIAC. MEDIA	VAL.GM	OBIETTIVO	EURI OBIETTIVO	Q.TA SCATOLA	NR. SCATOLE
MFC1S092	SALICE CERNIERA C2ABND9AC (FRENATA)	2 400,00	€ 3 351,14	€ 1,396	2 549	780	€ 5 167,737	780	€ 5 167,000	150	5,2
MFC1S044	SALICE CERNIERA C2ABA99(A94°) ASSORBE MFC1S021	48 600,00	€ 23 837,29	€ 0,490	2 682	8 799	€ 4 315,727	2000	€ 980,958	300	6,7
MFC1S093	SALICE CERNIERA C7A6ND9AC (FRENATA)	7 200,00	€ 10 034,29	€ 1,394	4 925	3 079	€ 4 291,053	500	€ 696,826	150	3,3
MFC1S080	SALICE CERNIERA C2ABG99 (90°)	32 700,00	€ 16 699,32	€ 0,511	5 731	7 333	€ 3 744,835	3000	€ 1 532,048	300	10,0
MFC1S085	SALICE CERNIERA C2ABGD9 (90°FREN.)	6 900,00	€ 6 325,84	€ 0,917	1 356	1 382	€ 3 393,034	500	€ 458,394	300	1,7
MFC1S003	SALICE CERNIERA CFA7A99(A94°)	9 300,00	€ 7 808,54	€ 0,840	3 831	3 701	€ 3 107,463	1000	€ 839,628	300	3,3
MFC1S075	SALICE CERNIERA FRENATA C7A6AD9	9 000,00	€ 7 360,39	€ 0,818	1 578	430	€ 3 026,756	430	€ 351,663	300	1,4
MFC1S537	SALICE BASE B2VGH49/17 (+L'EGO GG)	33 000,00	€ 3 092,65	€ 0,094	7014	11 220	€ 1 051,00	2000	€ 188,000	600	3,3
MFC1S526	SALICE BASE B2V6H49/17	30 600,00	€ 3 020,22	€ 0,099	2603	7 403	€ 730,00	7403	€ 732,897	600	12,3
MFC1S539	SALICE BASE DRITTA BAPGR39/16	28 800,00	€ 7 881,89	€ 0,274	1 449	1 300	€ 355,780	500	€ 136,838	300	1,7

Figure 78: Volumes of hinges bought from Salice in 2015, ordered from most to least value in-house per SKU.



CODICE	DESCRIZIONE	ACQ.2015	P.U.	GIAC. AD OGGI	GIAC. MEDIA	VAL. GM	OBIETTIVO	EURO OBIETTIVO	Q.TÀ SCATOLE	NR. SCATOLE
MFS1D001 400A	AMMORTIZZATORE PER GUIDA A RULLO	€ 90 072,00	€ 0,864	7 335	9 613	€ 8 305,632	2000	€ 1 728,000	450	4,4
MFS1M006	MUZZIN CP GUIDE SC.L=1400(12 SFERE)ART.GT55/140AP92-12 APERT 900K.BAN	€ 52 608,40	€ 6,416	1 407	1 028	€ 6 595,297	400	€ 2 566,263	200	2,0
MFS1M012	MUZZIN CP GUIDE SC.L=1600(11 SFERE)ART.GT55/160 APERTURA 1150	€ 11 875,00	€ 9,500	531	277	€ 2 631,500	277	€ 2 631,500	200	1,4
MFS1D001 400GFD	GUIDA DX A RULLO L=400 xFIANCOCOL.NERO 05 C/BUSS.d 8mm	€ 22 743,37	€ 0,238	9 244	9 036	€ 2 147,193	4000	€ 950,611	100	40,0
MFS1D001 400GCS	GUIDA SX A RULLO L=400 xCASSETTOCOL.NERO 05 C/BUSS.d 8mm	€ 19 865,26	€ 0,208	9 044	9 154	€ 1 900,173	4000	€ 830,314	100	40,0
MFS1D001 400GCD	GUIDA DX A RULLO L=400 xCASSETTOCOL.NERO 05 C/BUSS.d 8mm	€ 19 865,26	€ 0,208	9 344	1 534	€ 318,425	4000	€ 830,314	100	40,0

Figure 79: Volumes of drawer rails bought from Muzzin in 2015, ordered from most to least value in-house per SKU.

Alf's supply chain had some level of disorganization. Each plant had independent orders, and each operated as internal management sought fit. To the group, this represented an over-ordering and high levels of stock.

On figure 80, a value stream map scheme of the supply chain's modus-operandi can be observed. Let it be noted that "Terzista" refers to customers or stores to be supplied by Alf, which is represented by CRD and FRD, the codes to the plant in Cordigliano and Francenigo, respectively. "Fornitore", Italian for supplier, represents a random supplier, in this case, distanced further than 100 km.

CRD and FRD each supply different clients, independently. Their suppliers, treat them as if they were two different, independent companies. Each of the plants operate as warehouses, as well as productive plants.

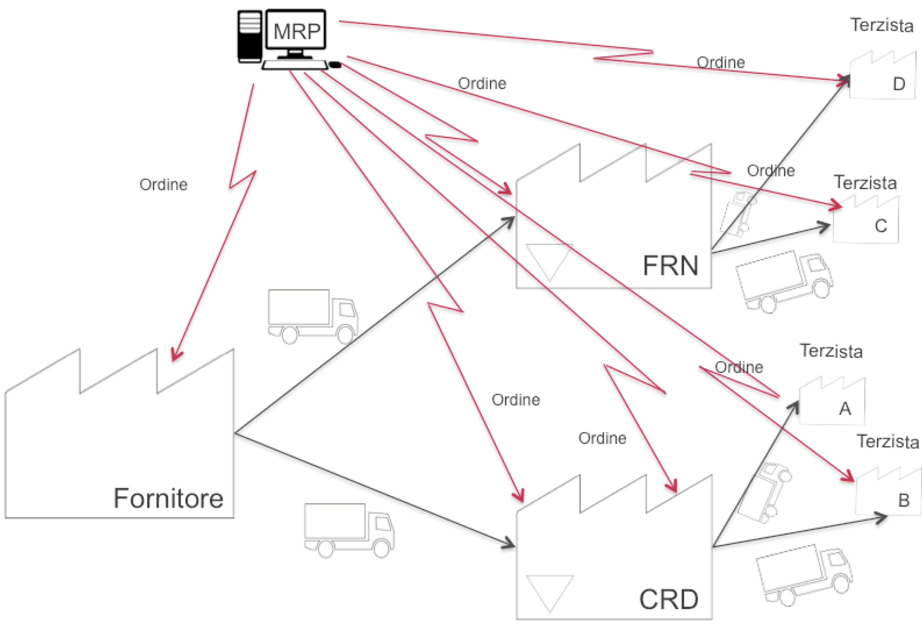


Figure 80: Alf's supply chain before the intervention, using VSM.

5.3 Proposed solution

A supply chain redesign was carried, visible in Figure 28. This was accomplished through the establishment of milk-runs, use of Kanban signals for replenishments (avoiding bullwhip effect) and synchronizing requests inside the group and other entities to be supplied. By doing this, it was possible to arrange at least one replenishment a day, reducing heavily the quantities in-house.

This supply chain redesign also allows the company to start functioning with pull flow, avoiding over production.

When a certain number of boxes is consumed, Kanban from customers and from the CRD center (represented as "Terzista" and "CRD") are sent to FRN, who prepares a lorry with the needed amounts, and delivers in the form of a milk-run, once a day.

FRN, having consumed several boxes, due to the *Kanban* signals received, then sends their needed amounts, also through a *Kanban* production signal to the supplier, which replenishes the needed levels, at least once a week.

The new engineered supply chain (figure 81) and logistic loops will allow more frequent replenishments, thus implying smaller batch delivery. This will directly impact the value and quantity of stock.

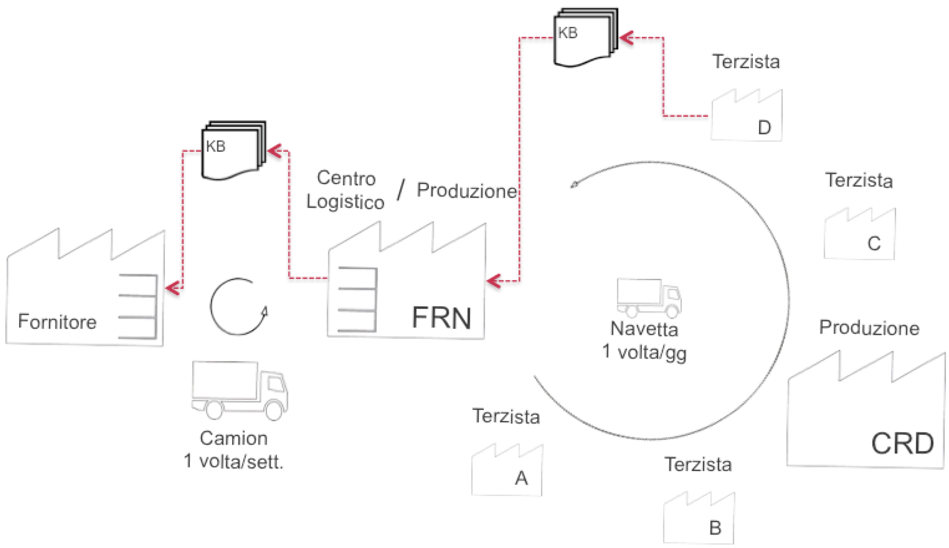


Figure 81: Alf's redesigned supply chain loops, after VSD.

In order to decide upon the quantities to store, a study on the risk of supply were carried. In order to understand supplier's behaviors and consequences, a Kraljic Matrix and a Supplier Strength / Distance ratio mas carried out.

On figure 82, the Supplier Strength (value supplier represents in warehouse capital) / Distance ratio allows us to measure the supplier's capability of frequent supply. A supplier which is up to 100 km away from CRD, can supply once a day, whereas a supplier further than 100 km will probably only be able to supply with a frequency of once a week.

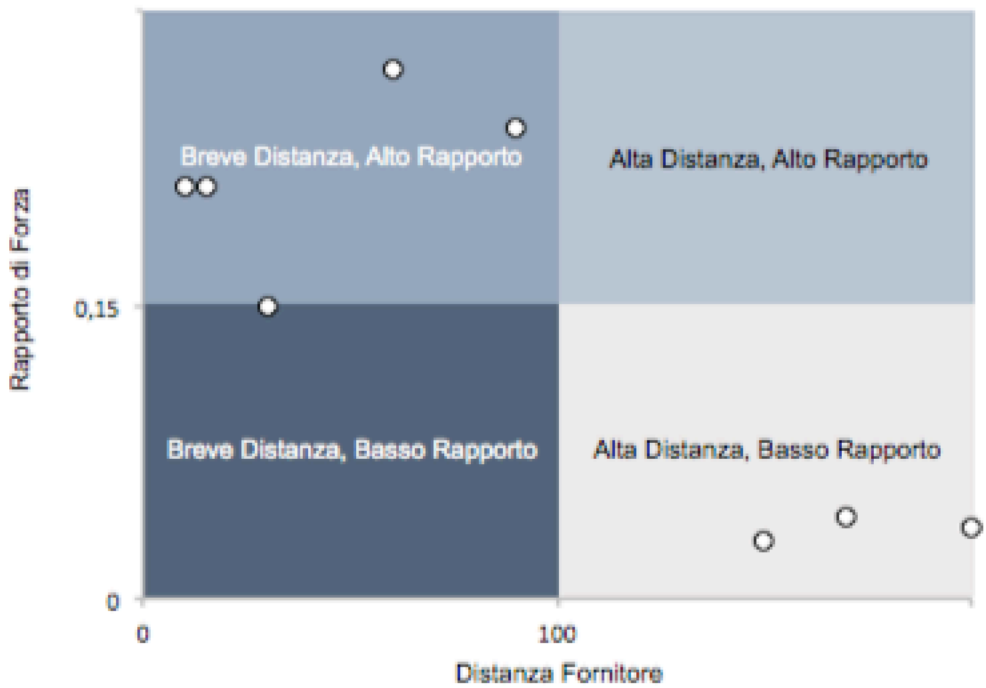


Figure 82: Mapping of supplier impact based on revenue representation and distance. (> 15% income = low rapport, < 15% income = High rapport, > 100 km = High Distance, < 100 km = Short distance).

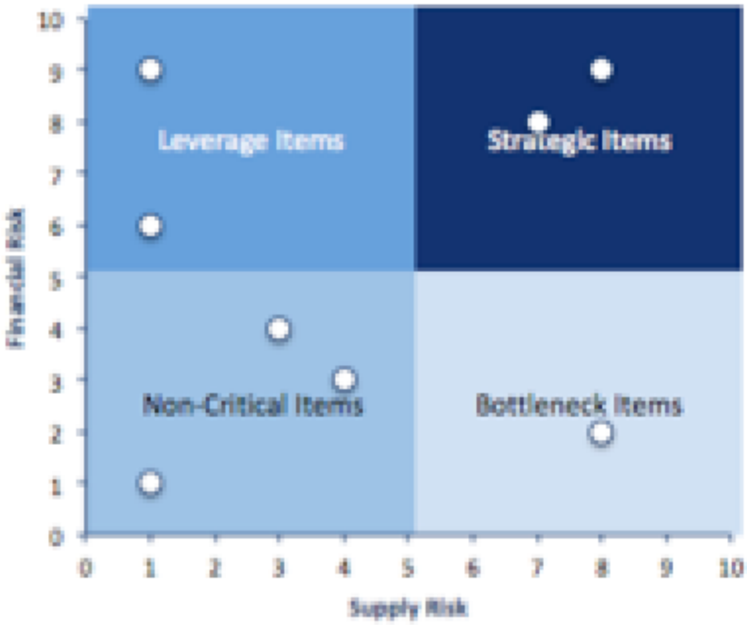


Figure 83: Kraljic Matrix for supplier risk assessment.

Through the analysis of the Kraljic's Matrix (figure 83), items from a specified supplier can be classified in order of criticality, allowing either a bigger or smaller dimensioning of safety inventory. The higher the risk of supply and the lower the financial risk, the more should be stocked. The lower the risk of supply and the higher the financial impact, the less should be stocked, and the more frequently should be ordered and delivered.

Limiting the allowed amounts in-house is also crucial to guarantee low-stock levels.

In order to do it, it was necessary to measure consumption based on cycle-time, delivery and replenishment time. The standard allowed quantities issued can be observed on figure 80, and they correspond to the supplier Salice.

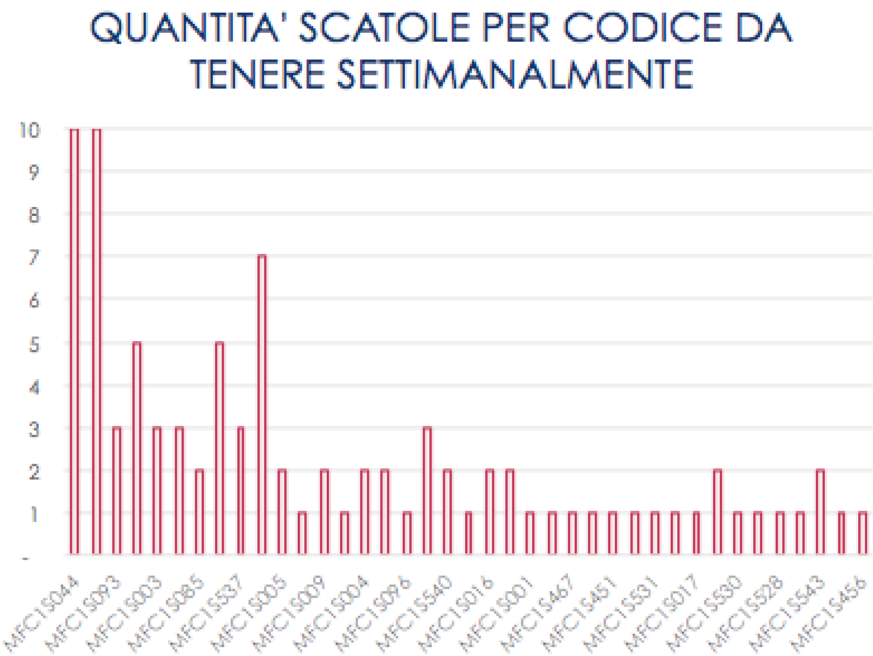


Figure 84: New standard – quantity of Kanban boxes allowed in the supermarket, for a weekly consumption.

To ease the replenishment of the Kanban boxes, a form was created, represented in Figure 85. By checking the consumed boxes, and labeling the code of the products consumed, it is easy to account fluctuations of consumption, and swiftly reorder from the supplier (to be filled on the top-right corner). This sheet can later be digitalized and sent to the supplier, functioning as a Kanban card, ordering multiple small batches (figure 86 illustrates a filled in sheet, being photographed and sent).

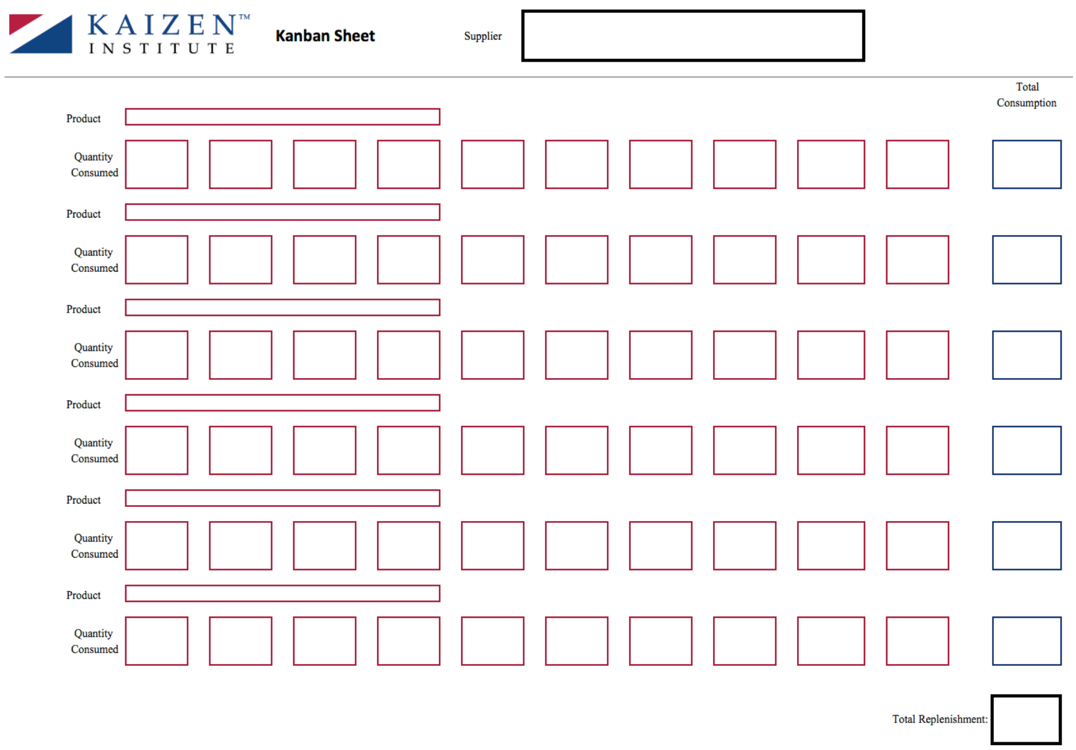


Figure 85: New standard - *Kanban* replenishment sheet, for weekly consumption.

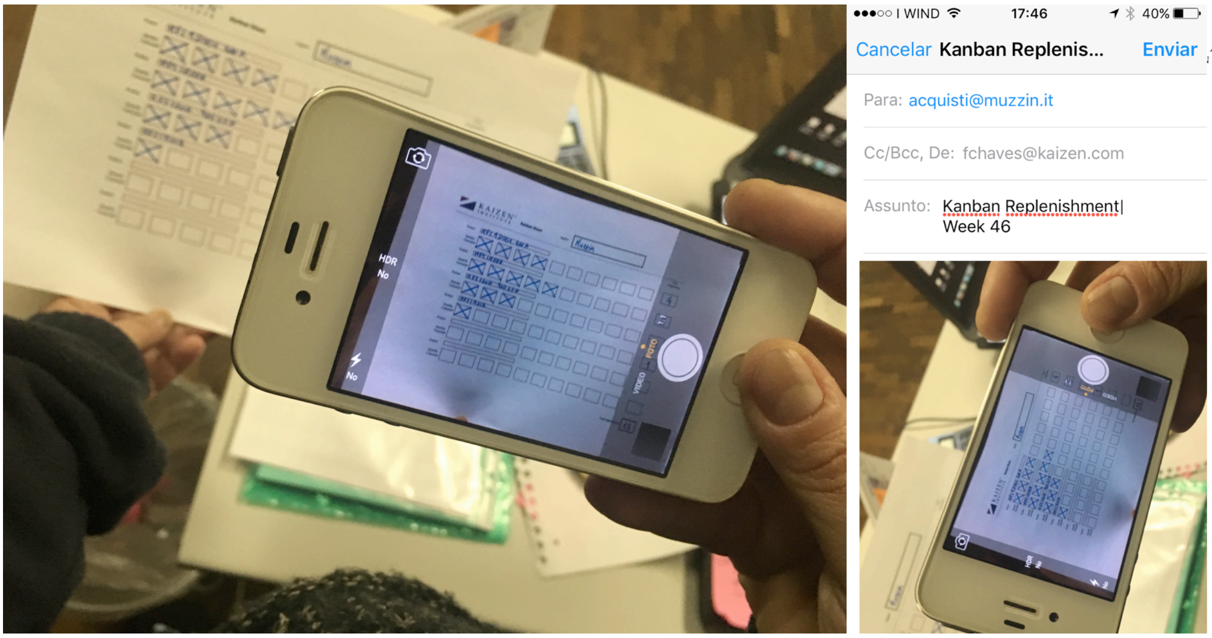


Figure 86:Example of the *Kanban* sheet in use: Photo of filled sheet being sent to supplier.

A proposal of partnership forms with suppliers was developed, aiming to increase the rapport, and strengthening the quality of supply. By establishing an annual agreement, with a defined budget, it is possible to ask the supplier to adapt its delivering methods, be it logistically, in terms of quantity and qualitatively, justifying the adaption to the *Kanban* system.

It also allows the suppliers to predict their income, to level production, avoiding high production peaks, or low production levels.

Orders are also simplified, being agreed upon consumption, and reducing the delivery addresses to only one.

It also brings the big advantage of assuring a promise of a minimum annual business level, which eases investment risk for the supplier.

5.4 Commentaries

The project was carried out effectively, in a very short term. Due to a very neutral non-participating team from the receiving company, very little resistance to change was found. Although this inertia compromised the development of creative ideas, and did not contribute to the establishment of a Continuous Improvement philosophy in the company, it did allow the consulting team to carry detailed analysis and best-practice decisions.

It was fundamental to carry a very detailed study in order to develop procedure manuals to apply to every supplier, and in this sense, autonomy was a must.

More involvement of Alf's team would have been positive in order to better understand problems in implementation and adapt in a swifter way.

5.5 Implementation results

With the measures taken, it was possible to reduce a total of 83 000 €, analyzing only two suppliers. Naturally, these were the most representative suppliers, and were chosen as pilot projects, in order to create manuals, exemplifying the modus-operandi to be followed.

Having done this, 41,5% of the 200 000€ goal was reached (10,3% of the global warehouse merchandise value), and with minimal investment. The measures to carry on are continuous supplier development and adaptation to Kanban system, through the establishment of partnerships, beneficial for both parties.

Further shortening of in-house allowed quantities, supply chain improvement, with logistic costs reduction and partnering up with local companies for logistic purposes is, as well, a direction to follow.

It was also understood that distance plays a very important role in frequent deliveries, urging the need for bigger quantities and increasing stock value. This means, that in order to continue their journey in *Lean* Management, Alf must start selecting closer suppliers, or renegotiate warehouse costs.

Chapter 6: Comparison between scenarios and discussion

6.1 Cases Comparison

Comparing the three Scenarios presented stands no easy task. Scenarios A and B, despite having received similar approaches, have serious differences in their type of industry and market. Geographical location also distinguishes them. Scenario C, with a completely different theme, also different in industry, had an intervention from a theoretical point of view, having received intervention in a very specific problem.

Comparison can be done, however, in the levels of implementation difficulty, resistance to change and team involvement

The team from Scenario A: Lacked motivation to improve, did not have clear understanding on *Kaizen* concepts (there was no time for *Kaizen*). The team was, however participative during workshops. They had some degree of resistance to new solutions and new paradigms. Paid no attention to KPI's.

The team from Scenario B: Very motivated to improve, had a minimum level of understanding of *Kaizen* principles. The team was participative during the workshops. They had some degree of resistance to new solutions and new paradigms. Paid no attention to KPI's.

The team from Scenario C: Participated scarcely, was unprepared and non-resistant. They did collaborate very much in providing information, details and data. Paid no attention to KPI's.

In figure 87, comparison between teams is summed up. The "*Kaizen* Process" was used to compare motivation, power of observation and following procedures, capacity of generating ideas and new approaches, capacity to implement and willingness to follow new standards.

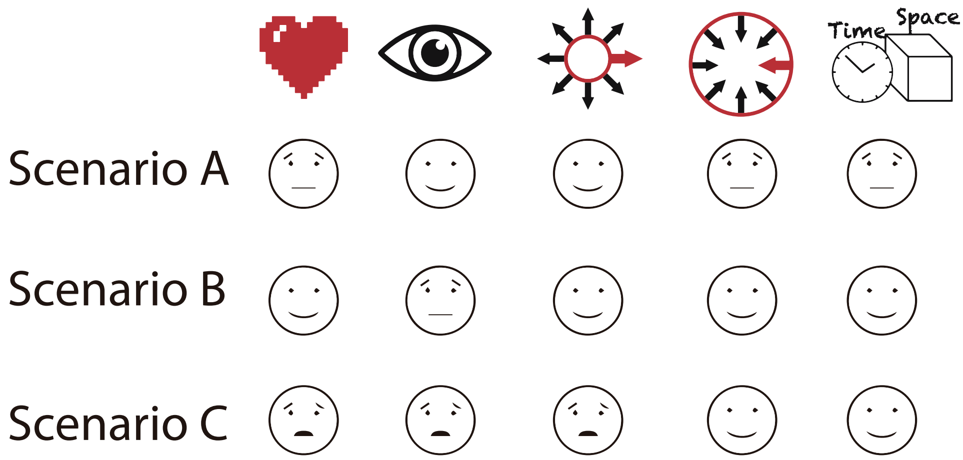


Figure 87: Comparison between the three scenarios' teams, based on an emotion scale against the *Kaizen* Process.

Figure 84 allows to comparison between the results achieved after SMED in both Scenarios A and B.

Company	Cost of Setup (€/h)	Setup Time Before (h)	Setup Time After (h)	Time Saved (h)	Money Saved Per Setup (€)	Number of Setups / Year	Yearly Savings (€)
Rossi	90	4,5	2,33	2,17	195,3	130	25389
Brevini	90	1,5	0,2	1,3	117	192	22464

Figure 88: Comparison of SMED results between Scenario A and Scenario B.

6.2 Discussion

Figure 89 allows a quick graphic comparison between the results achieved in each Scenario. The figures showed represent some of the the results achieved after selected workshops in each company, the pilot projects which can be considered a success during *Kaizen* Institute's intervention.

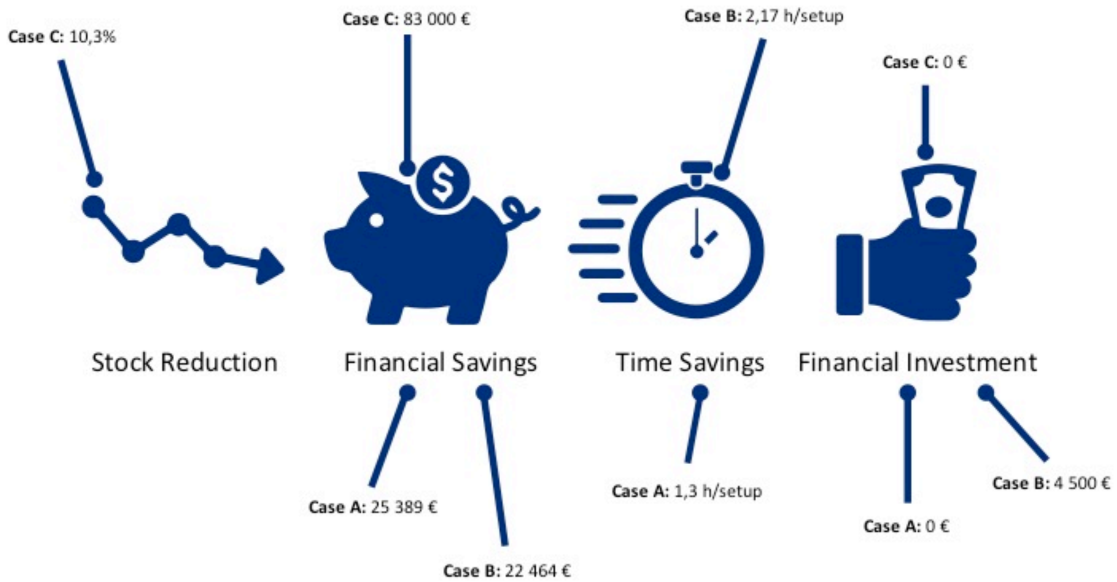


Figure 89: Infographic comparing Scenarios A, B and C based on stock reduction, financial savings, time savings and financial investment.

Scenario B, for example, had a longer intervention than Scenario A, having had, in the global system, more machines exposed to SMED, 5s and preventive maintenance, meaning that in terms of reliability, Scenario B did in fact achieve better results, despite being shown on the figure, bigger financial winnings for Scenario A.

Scenario B had, as well, higher investment (due to the fourth step of SMED), because machine transformation was done. This doesn't necessarily mean more money was spent than on Scenario A: the goal was always to reduce the time a machine was shut-down, increasing the productive time and enabling fast setups. In this sense, Scenario B is much more ready to supply different products, in smaller batches, thus supplying its supermarkets more efficiently. The 4 500 € euros invested in the fast-bolting system should be amortized by the 24^{th} setup, following the new standard.

Due to team involvement and commitment, both Scenarios A and B suffered slight cultural changes, approaching a *Kaizen* culture. Scenario C, due to the low-involvement in the projects, saw little or no changes to their culture.

6.3 Summary

Scenario B and C had much more committed teams to follow implemented solutions than Scenario A. This is thought to be due to the economic intervention from the Italian state, “Cassa Integrazione”.

Scenario B did in fact arrive nearly to a Single Minute setup, while Scenario A did not. This difference can be justified by the following of method and procedures of SMED. In Scenario A, the method was only lightly approached and discussed out load. Visual management did, in fact, make a difference between these two Scenarios.

Neither of the teams from Scenarios A, B and C paid attention to KPI’s and data collection. Their struggle laid on the fact that in neither company’s culture, was an urge from top management to follow scientific management. Also, collecting data was complicated, as the operators in each company were not trusted to provide data, or trained to read it, interpret it and act based on the information conveyed through numbers.

During implementation, Scenario B brought the most problems up, mainly due to the local syndicate, and the fear of job reductions. Scenario A, in the meantime, was relatively neutral, arising problems, but always quickly solvable. Scenario C, was, on the other hand, very easy to deal with, as resistance was minimum and all suggestions of improvement were welcome.

Chapter 7: Conclusions and future perspectives

7.1 Conclusions

Upon arrival in all three Scenarios, it was clear that improving opportunities were infinite. In the Scenarios where Total Productive Maintenance was applied, both companies were operating based on hunch, with no data support. This meant decisions weren't calculated, nor aligned with the companies objectives. In Scenario C, the division inside the groups companies was impeding control on stock and acquisitions.

In Scenarios A and B, a big effort to educate on metrics, KPI's was done. This argument was important to motivate the teams into improving their machine maintenance. Both teams had difficulties in understanging why machine up-time was so important, and why reducing setup times were so crucial. After explaining their important role in the Total Flow Management model, all teams started to understand that they were a fundamental piece.

The SMED method was proven to be extremely efficient in the reduction of setup times, having reached reductions in the order of 48,1% (Scenario A) and 86,2% (Scenario B). These reductions allow both companies to produce in smaller batches, feeding more frequently the supermarkets needed to support efficient internal logistics.

In Scenario A, the total time savings in only one machine result in 25 389 €/year, which also represent 260 h of dedicated work to setup saved. These savings also allow the company to start saving on warehouse costs, as now batch sizes can be reduced to 50%. Besides, the setup time after SMED treated in this dissertation was only the first iteration and can surely arrive to single minute, with continuous improvement.

In Scenario B, the total savings in only one machine summed up to 22 464 €/year, with the current number of yearly setups. The invested time in machine setup passed from 285 h/year to 38 h/year, thus saving 247 h, or two whole days a year, that were exclusively dedicated to setup. This time can now be used for production, reducing the opportunity cost, and allow the company to produce smaller batches.

The 5s actions also brought big improvements in both Scenarios A and B, having improved levels of productivity and motivation in the shopfloor. These actions brought more safety to the shopfloors, and more ergonomy. By having clean workstations, deffect levels also were reduced, due to correct work conditions. Both companies still have a long road ahead, and both must regard 5s as continuous activity to perform and persue.

The TPM action conducted in Scenario B has mitigated malfunctions and breakdowns in the machines intervented, thus highly increasing machine reliability. This has been accomplished, not with over complex reasoning and theory, but with simple, common sense: avoiding problems, solving root causes and sustaining a minimum standard of cleanliness and function.

In Scenario C, results were very positive. In such a short term, 41,5% of the global objective was met. This means 83 000€ were saved after analysing only two suppliers. After these results were met, manuals were produced and delivered to reproduce the changes with different suppliers, being believed that once the project is over, the 200 000€ objective will be very well accomplished, with even more savings than expected. In the end, *Kaizen* Institute was re-hired. In a global view, a 10,3% reduction of the company existing stock was achieved.

Scenarios A and B did, however, arise many problems in terms of change management. Political strengths, such as syndicates, did compromise the implementations' speed. Learning to negotiate with these parties is a key aspect in order to correctly implement *Lean* management systems in Italy.

7.2 Tools and their technical and emotional effect on change

Throughout this work, many obstacles were found, namely in the fields of resistance to change.

Most of the tools used, were selected because of their technical and emotional effects on the teams.

Tool	Business Effect	Change Management Effect
5s Game	Instruction, Training	Creates desire to perform
Excel Dashboard	Software, Time saving, Analytics	Simplifies data collection, Reduces fear
SMED	Setup reduction, Methodic process	Focus, Abstraction, See rather than watch
Red Maintenance Card	Signal problems, Visual understanding	"Expel" the problem
PDCA	Analysis method, problem solving tool	Show others, Remember, Impress

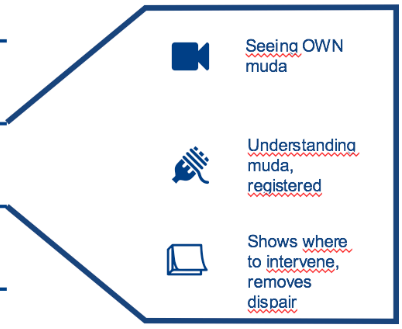


Figure 90: Tools used during the work, with business and change management effects.

The 5s game, allowed the teams to understand the importance of good house-keeping, and urged them to accept it as a good-practice, clearly stating the benefits. By employing the concepts, the teams could understand the method, and generate ideas for implementation.

The excel dashboard brought a technical approach to the company, but it also helped demystify the complexity of collecting data. By showing, as well, how to manage actions based on the dashboard, the fear of judgment was reduced.

The SMED process, does allow drastic reductions in setup, however, it is mainly accomplished through several steps that help the teams understand and react to problems.

By showing the operators their movements traced on a spaghetti chart, and showing them on a film, reduces discussion and reluctance in accepting a non-optimized process, preparing them for change. The use of colored "post-its" works not only as a technical method, but also as a way to indicate where intervention is needed, and how it must be done.

The red cards used in the maintenance scheduling, besides clearly indicating problems and encouraging solutions, also allow the operator to "expel" the problem from his workstation, helping thus, in the maintenance of the workstation, and avoiding repetition of problems.

The PDCA tables, visible in the middle of the *Gemba*, were seen to motivate operators that hadn't yet worked with *Kaizen* tools. They would stop in front of the charts, analyze them, register the improvements, and ask for similar help. Naturally, from a technical point of view, the PDCA was seen to be fundamental in planning, deploying, verifying results and extending them to the rest of the organization.

7.3 Future Work

It is recommended, in future interventions, that work must only be started once information and data is provided. It was noted during implementation, that once a topic sounded complex, initial data would change, unjustifying the need to improve. Having a detailed report surely will help to keep a tighter grip during the project management.

It is also recommended, that some of the change management actions, briefly described in this thesis, are employed during deployment of the implementation, such as games, thought sequences of implementation and interactive dashboards. These elements, when wisely used, drastically reduce resistence and improve the chances of the company accepting and employing the new solutions.

When managing similar projects, pressure must be done to educate, involve and develop shopfloor workers, thus improving the Gemba. Some of the actions described in this thesis failed on the first iteration due to the non-involvement of operators, despite external insistence.

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